WHITE PAPER

USDA Forest Service Pacific Northwest Region Umatilla National Forest

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Range of Variation Recommendations for Dry, Moist, and Cold Forests[1]

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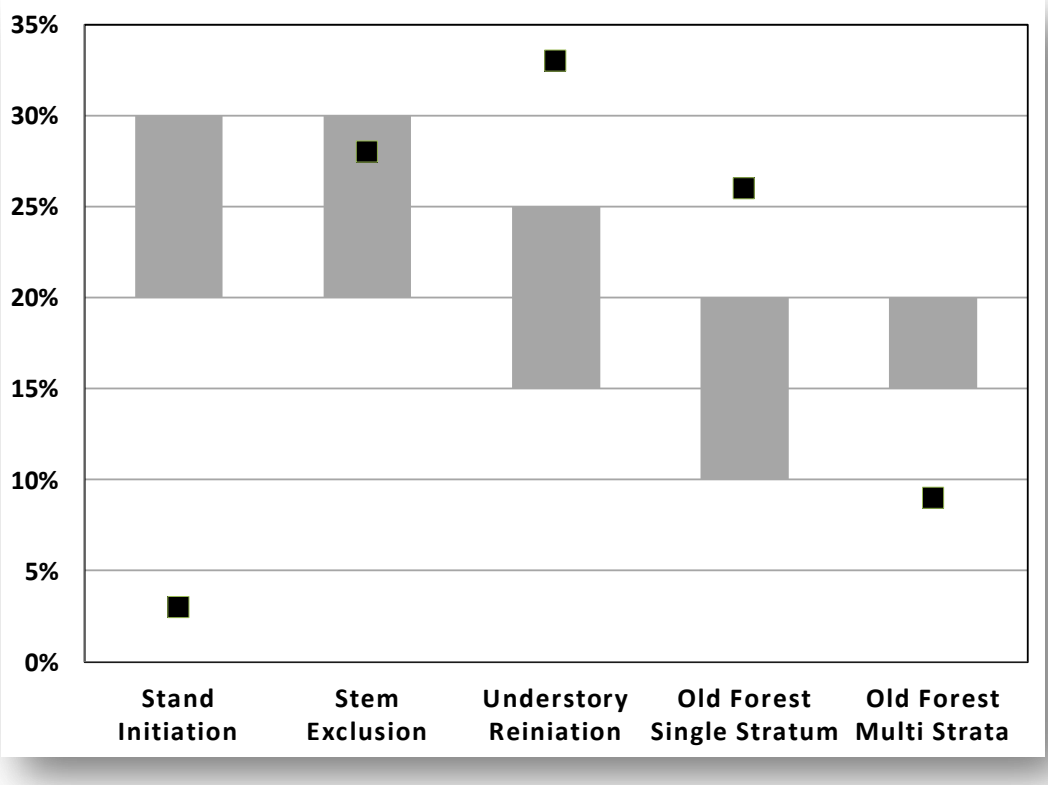

[1] White papers are internal reports receiving only limited review. Viewpoints expressed in this paper are those of the author – they may not represent positions of the USDA Forest Service.

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INTRODUCTION

The range of variation (RV) is defined as the range of conditions likely to have occurred in the Blue Mountains prior to Euro-American settlement in the mid 1800s (USDA Forest Service 1996). The RV concept has been a recurring theme in forest ecology and management literature for at least two decades now (Aplet and Keeton 1999, Caraher and Knapp 1994, Christensen et al. 1996, Dodson et al. 1998, Egan and Howell 2001, Kimmins 1997, Manley et al. 1995, Millar 1997, Morgan 2004, Morgan et al. 1994, Morgan and Parsons 2001, Parsons et al. 1999, Quigley and Arbelbide 1997, Swanson et al. 1994, USDA Forest Service 1992).

"Considerable attention has been focused on natural disturbance processes as a guide for forest management. Concepts such as the historic range of variability (Landres et al. 1999) and coarse filter conservation strategies (Haufler et al. 1996, Hunter 1990) suggest that successful management of ecosystems may best be achieved by mimicking natural disturbance patterns and processes" (Wright and Agee 2004:443; Arno and Fiedler 2005, Perera et al. 2004).

Terminology note: Some sources refer to RV as the natural range of variability (Hessburg et al. 1999, Swanson et al. 1994) or the historical range of variability. Natural is an ambiguous but frequently used term to signify something of esthetic or spiritual importance (Christensen et al. 1996). Primarily to avoid this ambiguity, I use the term 'range of variation,' although this usage also agrees with Forest Service handbook and manual direction (see FSH 1909.12, section 43.13 – Range of Variation; and FSM 1920, section 1921.73a – Ecosystem Diversity). And in response to climate change, some sources suggest that the historical range of variability is no longer relevant (deBuys 2008, Fulé 2008) and should be abandoned altogether, or perhaps replaced with a 'future range of variability' (Duncan et al. 2010).

This white paper has six objectives:

1. Provide background and context explaining how an RV approach has been used in the Pacific Northwest Region of the U.S. Forest Service.
2. Describe certain concepts and principles related to the range of variation.
3. Describe how RV could support Forest Service planning processes.
4. Provide ranges of variation for species composition, forest structure, stand density, and related components (ranges are expressed as percentages and presented in a table for each component).
5. Provide a glossary of terms related to the RV concept.
6. Provide references and literature citations related to the range of variation.

BACKGROUND AND CONTEXT FOR THIS WHITE PAPER

In July 1992, a report was released called "Restoring Ecosystems in the Blue Mountains: A Report to the Regional Forester and the Forest Supervisors of the Blue Mountains" (Caraher et al. 1992). This document, often referred to as the Caraher

Report, was prepared by a panel of scientists who used nine indicators to assess ecosystem restoration needs for the Blue Mountains.

The Caraher Report was probably the first example in the Pacific Northwest to demonstrate how a concept called the historical range of variability (HRV) could be applied. The Northern Region of the Forest Service initially incorporated the HRV concept in their Sustaining Ecological Systems (SES) process (USDA Forest Service 1992); the Caraher panel adopted HRV and other SES principles for their Blue Mountains restoration assessment.

In March 1993, the Natural Resources Defense Council (NRDC) petitioned the Pacific Northwest Region of the U.S. Forest Service to halt all timber harvest activity in old growth forests on national forest lands located east of the Cascade Mountains crest in Oregon and Washington (this geographical area is traditionally referred to as the Eastside).

A month later in April 1993, a group of university and U.S. Forest Service research scientists released an "Eastside Forest Ecosystem Health Assessment;" this assessment is known as the Everett Report because it was directed by Dr. Richard Everett (Everett et al. 1994).[2] In response to both the NRDC petition and the Everett report, U.S. Forest Service Regional Forester John Lowe issued interim direction in August 1993 requiring that timber sales prepared and offered by Eastside national forests be evaluated to determine their potential impact on riparian habitat, historical vegetation patterns, and wildlife fragmentation and connectivity.

This interim direction, known as the Eastside Screens, was used to amend Eastside forest plans when Regional Forester John Lowe signed a Decision Notice on May 20, 1994 to implement Regional Forester's Forest Plan Amendment #1 (USDA Forest Service 1994). A slightly revised version of the Eastside Screens was issued as Regional Forester's Forest Plan Amendment #2 when Lowe signed a Decision Notice on June 12, 1995 (USDA Forest Service 1995).

The Screens' ecosystem standard requires a landscape-level assessment of the historical range of variability[3] for structural stages, including a determination of how existing structural stage percentages compare with their historical ranges. To my knowledge, the Eastside Screens are the first instance of the RV approach being used as a mandatory requirement for land and resource management planning. And I believe the RV concept is well suited for this role.

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[2] The Everett Report was prepared in response to a May 1992 request from U.S. House Speaker Tom Foley and U.S. Senator Mark Hatfield for a scientific evaluation of the effects of Forest Service management practices on the sustainability of forest ecosystems in eastern Oregon and eastern Washington. Over 100 scientists worked for more than a year on the assessment; final results were published as a series of general technical reports by the Pacific Northwest Research Station in 1994 and 1995.

[3] The historical range of variability (HRV) and the range of variation (RV) are used somewhat interchangeably in this white paper. HRV has long tenure, dating back to the early 1990s, but the Forest Service recently adopted RV as its term of choice for describing the variability of reference ecosystems (see FSH 1909.12, section 43.13).

CONCEPTS AND PRINCIPLES RELATED TO RV

The RV concept is used to characterize fluctuations in ecosystem conditions and processes over a period of time (fig. 1). It is now understood that ecosystem conditions change as disturbance processes affect them; when disturbances act with a characteristic frequency and intensity (severity), ecosystems respond by exhibiting a predictable behavior and level of complexity (Aplet and Keeton 1999, Morgan et al. 1994).

Figure 1 demonstrates that the effects of repeated disturbance events cause conditions to fluctuate between upper and lower limits, suggesting that nature does not function with perfect replication from one disturbance event to another. Assume the trend line in figure 1 shows fluctuations in old forest structure within a watershed. Over time as stands mature, old-forest acreage increases toward the upper limit until a disturbance process eventually transforms some of it into another structural stage, at which point the old-forest acreage declines toward the lower limit.

Fine-scale disturbance processes such as root disease cause small reductions in old-forest acreage; broad-scale processes such as crown fire or bark beetle outbreaks may result in dramatic old-forest declines. In the hypothetical example portrayed in figure 1, the ecosystem dynamics produced by disturbance processes describe a range of variation for old-forest structure.

As a concept, RV recognizes that ecosystem components have a range of conditions in which they are resilient and self-sustaining, and beyond which they move into a state of disequilibrium (Egan and Howell 2001, Holling and Meffe 1996).

If an ecosystem component should diminish to a point that never occurred historically, then it is assumed that natural processes alone will not be able to recover or sustain this component in the future (USDA Forest Service 1992). Holling and Meffe (1996) expressed this concept well when they noted that "management should strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resiliency."

RV is an analytical technique to characterize inherent variation in species composition, forest structure, and stand density, reflecting recent evolutionary history and the dynamic interplay of biotic and abiotic factors. "Study of past ecosystem behavior can provide the framework for understanding the structure and behavior of contemporary ecosystems, and is the basis for predicting future conditions" (Morgan et al. 1994).

RV is meant to reflect ecosystem properties free of major influence by Euro-American humans, providing insights into ecosystem resilience (Kaufmann et al. 1994, Landres et al. 1999). RV helps us understand what an ecosystem is capable of, how historical disturbance regimes functioned, and inherent variation in ecosystem conditions and processes – the patterns, connectivity, seral stages, and cover types produced by ecological systems at a landscape scale (USDA Forest Service 1997).

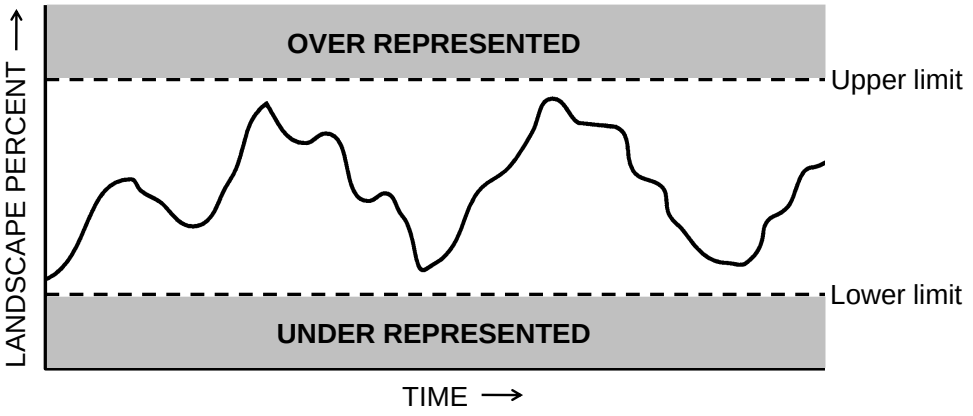


Figure 1 – The range of variation (RV) helps us decide whether existing amounts of vegetation composition, structure, and density, when summarized for a landscape-scale analysis area, are occurring within a characteristic range (Aplet and Keeton 1999, Morgan et al. 1994, Swanson et al. 1994). This diagram shows the ecological trajectory of an ecosystem component (the solid line) varying through time because the phrase 'range of variation' is meant to encompass more than just the extreme values (the upper and lower limits, shown as dashed lines) (diagram modified from Morgan et al. 1994).

RV is a good example of the dynamic equilibrium concept because modal or central-tendency conditions obviously vary over time (shown by the squiggly solid line in the center), and yet they vary within an equilibrium zone whose limits (the dashed lines) are confined within a range of potential ecological expressions. Note that conditions occurring above the upper limit are considered to be over-represented; conditions below the lower limit are considered to be under-represented (the representation zones are gray).

ECOSYSTEM VARIATION AS A FOUNDATION FOR RV

RV is not intended to portray a static, unchanging condition. Ecosystems of the interior Pacific Northwest evolved with a steady diet of wildfire, insect outbreaks, disease epidemics, floods, landslides, human uses, and weather cycles. Change was, and still is, the only constant in their development. RV is designed to characterize the range of vegetation composition, structure, and density produced by these agents of change (Morgan et al. 1994).

The first generation of American ecologists was led at the start of the twentieth century by Nebraska scientist Frederic Clements. Clements and his University of Nebraska collaborators (particularly Charles Bessey and Rosco Pound) believed that plant succession caused ecosystems to develop in a predictable sequence of steps – much the same way as a human infant matures into an adult. Proponents of this super-organism philosophy maintained that individual species were linked together in mutually beneficial systems exhibiting properties greater than the sum of their parts (Clements 1916, Egerton 1973, Wu and Loucks 1995).

Clements contended that nature was orderly, and that its order was for the most part stable and self-regulating. He assumed that the normal condition of ecosystems was a state of homeostasis or equilibrium – a forest grows to a mature climax stage that becomes its naturally permanent condition (Clements 1916). Many contempo-

rary ideas about the environment are based on Clements' notion that nature is capable of retaining its inherent balance more or less indefinitely if only humans could avoid disturbing it (Cronon 1996, Shugart and West 1981).

Contrary to Clements' claims, subsequent work has shown that the normal state of nature is not one of balance; the normal situation is to be recovering from the last disturbance. Change and turmoil, rather than constancy and balance, seems to be the rule. We now know that the concept of a forest evolving to a stable (climax) stage, which then becomes its naturally permanent condition, is incorrect (Botkin 1990, Stevens 1990). In many areas and particularly in the interior Pacific Northwest, large-scale disturbances are common and development to a truly stable climax is rare or absent (Kipfmuller et al. 2005, O'Hara and others 1996).

"As Clementsian climax theory fell out of favor, ecologists increasingly resorted to concepts such as the historical range of variability to bound their understanding of a system's innate potential. But for HRV to have utility, the range of variability must have reasonably fixed boundaries, which are largely determined by climate and edaphic factors. When climate changes substantially, the boundaries can weaken and ranges of variability can wobble off course" (deBuys 2008).

Historical ecology can teach us what worked and what lasted – how resilient ecosystems sustained themselves through time (Swetnam et al. 1999). The type and frequency of presettlement disturbances can serve as a management template for maintaining sites within their historical range of plant composition and vegetation structures – if landscapes can be maintained within RV, then they stand a good chance of maintaining their biological diversity and ecological integrity through time (Aplet and Keeton 1999, Holling and Meffe 1996).

An RV approach ensures that management activities are consistent with the conditions under which native species, gene pools, communities, landscapes, and ecosystem processes evolved (DeLong and Tanner 1996). It is typically assumed that presettlement conditions represent optimum habitats for native plants and animals, and that the best way to recover an endangered or threatened species is to restore its habitat to some semblance of presettlement conditions (Botkin 1995).

Since a key premise of RV is that native species have evolved with, and are adapted to, the historical disturbance regimes of an area, ecosystem components occurring within their historical range are believed to represent sustainable conditions (Aplet and Keeton 1999, Swanson et al. 1994). At a landscape scale, for example, a forest might be considered healthy and sustainable if the spatial and temporal patterns of its composition, structure, and density are within RV.

RV is used as a tool to help us understand present forests and why they respond as they do when exposed to management practices – it uses the past to help us understand the present, to understand which forces affect vegetation response, to gain insight into possible trajectories of future forests, and to integrate this information when proposing management alternatives (Millar and Woolfenden 1999).

RV AS A PLANNING TOOL[4]

Beginning in the early 1990s, a long-standing debate intensified about the purpose of national forests and their contribution to American society. This debate demonstrates that certain segments of American society prefer federal forests to function primarily as old-growth reserves, or to provide essential wildlife habitat. Other Americans believe that public wildlands should offer recreational opportunities as their primary purpose, whereas some feel they should be managed to supply commodities such as timber, livestock forage, minerals, and water.

The purposes for which national forests are managed are broadly established in federal law, and then refined for each individual unit through a planning process incorporating public input. But the goals and objectives for which a national forest is to be managed cannot be exclusively a matter of public (societal) preference.

Biophysical factors dictate a range of ecosystem states that are possible for an area, historical factors such as wildfire and timber harvest determine what is present there now, and both sets of factors ultimately control the societal choices available at any point in time (fig. 2). Forests adapted to a dry temperate climatic regime, for example, cannot be made to take on the characteristics of moist tropical forests, even if they are highly desired by society – in this instance, the biophysical site potential would obviously trump societal desires.

A good example of the biophysical potential concept is provided by the open and parklike forests historically created and maintained by surface fire (fig. 3). On warm dry sites such as those in figure 3, an historical process (frequent surface fire) maintained large, widely-spaced, fire-tolerant trees over an undergrowth so free of brush and small trees that settlers could often drive their wagons through the forest as if it was a carefully manicured park (Evans 1991, Munger 1917).

By disrupting the short-interval fire regime on dry sites, society unintentionally decided to replace the open, parklike condition with a dense, multi-layered structure. It is possible for dense forest to exist on warm dry biophysical environments, but only at a high potential cost in terms of future susceptibility to uncharacteristic fire effects and insect or disease impact (Agee 1994, Hessburg et al. 1994, Huff et al. 1995, Lehmkuhl et al. 1994, Mutch et al. 1993, Wickman 1992).

And if land management policy continues to emphasize systematic fire exclusion for dry-forest sites, society should acknowledge that when fire returns to them, as it inevitably will, our socio-economic systems and associated infrastructure are willing and prepared to accept the consequences of an exclusion policy, including the attendant side effects of uncharacteristic fire behavior and undesirable fire effects.

[4] This section discusses RV in the context of broad planning concepts and principles; for a description of how RV is used to support fine-scale project planning processes, refer to a section called "Project Planning and RV" later in this white paper (page 17).

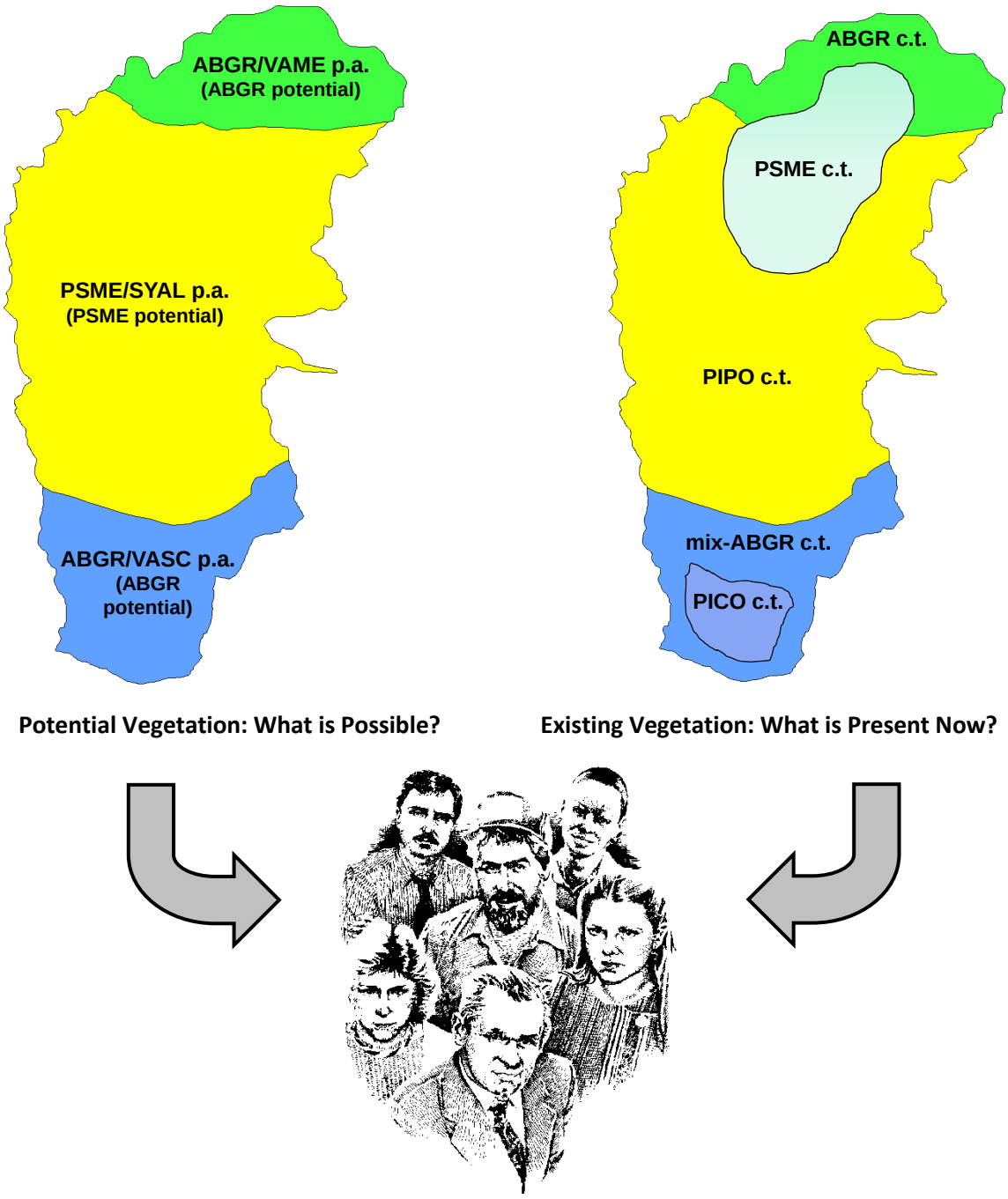


Figure 2 – Developing desired conditions for land management planning is a societal process. RV should not be used as a desired condition, but it can function as a baseline to help society understand the biophysical potential of ecosystems (upper left, showing three plant associations (p.a.) and their tree species potential: ABGR is grand fir; PSME is Douglas-fir; PIPO is ponderosa pine; PICO is lodgepole pine). After establishing a biophysical template, existing conditions for composition (upper right; c.t. is cover type), structure, density, and other ecosystem components can be compared with reference conditions (the RV). Using RV in this manner could help society develop desired conditions because it integrates potential vegetation (what is possible) with existing vegetation (what is present now).

Figure 3 – Open ponderosa pine forest with herbaceous undergrowth (stand of old-growth *Pinus ponderosa* near Whitney, Oregon, ca. 1900 [J. W. Cowden]; courtesy Gary Dielman, Baker City library). Pioneer journals (Evans 1991), early surveys (Gannett 1902, Munger 1917), and fire history studies (Heyerdahl 1997, Maruoka 1994) suggest that many dry-forest sites in the Blue Mountains had presettlement conditions resembling this image, particularly for the Douglas-fir/pinegrass and grand fir/pinegrass plant associations (Weaver 1967). The combination of a warm dry temperature-moisture regime and a disturbance regime featuring surface fire created the distinctive composition and structure shown here. Some studies concluded that this ecosystem condition reflects a long-term cultural practice because traditional human uses (Native American burning and associated plant species utilization) were important for sustaining the biodiversity and productivity of these ecological settings (Boyd 1999, Vale 2002).

It is likely "that the high costs and consequences of excluding necessary ecological processes (e.g., fire) will soon shape human desires and decisions more than they have in the past" (Swetnam et al. 1999). Now that large fires are occurring at an unprecedented rate (Bennett 2000), consuming steadily increasing proportions of the Forest Service's annual budget allocation, and transferring project-level funds away from resource management functions and into fire suppression accounts, it appears that the "high costs and consequences" of fire suppression are finally being realized at the federal government level (GAO 1999).

When considering that dense, dry-site forests have existed for more than a half-century in many portions of the western United States, society is now faced with an interesting dilemma:

- If the current cohort of natural resource managers has grown accustomed to dense, mixed-species forests on dry sites, perhaps now accepting them as the norm and assuming they can be perpetuated into the future;
- Then society must acknowledge that if we can successfully restore the short-interval fire regime and its historically open stand density, these conditions will be ill suited for providing wood, elk cover, and many other services that society has come to expect from dense dry forests (Gruell 2001, Moore et al. 1999).

In contrast to the dry-forest situation, forests with a moist biophysical potential cannot be sustained in a parklike condition without constant tending by using activities such as timber harvest or biomass removal. The biophysical factors influencing moist environments would allow some of them to be maintained in a parklike condition if this is society's objective, but only with substantial human intervention because the native disturbance regime created little or none of this condition on its own (and never across substantial acreages).

These examples are designed to demonstrate that society must first strive to learn what the normal or characteristic 'state of being' is for an ecosystem type (in the context of biophysical potential and associated ranges of variation), and then to use this knowledge to inform natural resource policy and decision making (fig. 2).

A fundamental tenet for hierarchical analysis during planning is: at whatever scale planning is occurring, look up one level to obtain context, and look down one level to understand process (Haynes et al. 1996, O'Neill et al. 1986). As an example of hierarchical analysis, let's say that a range of variation (RV) analysis has identified a particular watershed as a candidate for harvest of old forest structure because it is currently 'above RV' with respect to this structural stage (i.e., old forest abundance exceeds the upper limit of RV – see fig. 1).

Continuing with this example, however, it would be important to evaluate RV at the next highest hierarchical level (the subbasin scale in this example) because without such information, an analyst would be unaware of the watershed's contribution to old-forest structure in the context of the subbasin – and such knowledge might have an important influence on the tree harvest decision-making process.

If it turns out that the subbasin also exceeds RV for old-forest structure, or if it occurs within the range but at the high end, then targeting the watershed for tree harvest might be an appropriate and reasonable approach. On the other hand, if the subbasin is below RV for old-forest structure, then deferring tree harvest in the watershed may be prudent until old forest abundance at the subbasin scale is restored to an ecologically appropriate level.

This same approach can be used through all hierarchical levels – RV could be assessed at the broadest scale first, then stepped down to the next lowest level, reassessed, and so on down to the site or stand level. It can also be used with a full suite of ecosystem components or categories of interest – a forest landscape in synchrony with RV would not only provide old forest at an appropriate abundance and configu-

ration, but it would also contain young and mid-age patches with size, shape, composition, and structure all occurring within RV for these ecosystem elements (Aplet and Keeton 1999, Morgan et al. 1994).

When we think about scale, a spatial example typically comes to mind. But temporal scales are also important. The time scales associated with landscape pattern and structure range from years to centuries, but variations in stream flow or bank structure can sometimes be measured in days, and biome-level changes may span millennia. Forest vegetation often requires hundreds of years to develop to its full expression, and erosion processes frequently span thousands of years (Eng 1998).

An appropriate temporal perspective is important because "how can human communities manage landscape change that takes place over a hundred years or more, when people's perceptions and priorities change from generation to generation, or even from election to election? Humans may not have the right 'attention span' to manage environmental change, and this may be the species' fatal flaw. Perhaps this is the value of history – as an attempt to extend the time frame of our memory beyond the human lifetime. The only problem is that history represents selective memory" (Spirn 1996).

RV AS A BASELINE

RV can appropriately serve as a baseline from which change can be measured; it is not designed to provide a specific condition for active restoration purposes, although RV could provide a useful framework for evaluating restoration alternatives (USDA Forest Service 1997). [But also note that collaborative or consensus groups are often interested in using presettlement conditions as a restoration objective (Christopherson et al. 1996)].

A common misconception is that it might be appropriate to use RV as a management objective by linking desired conditions directly to RV, but a better approach is to let reference conditions and historical data inform an analyst about the potential behavior and expected consequences of restoration treatments (Millar 1997).

"If ecosystems are necessarily dynamic, then it may be misguided and fruitless to choose a single fixed point or period of time in the past for establishing a static, desired future condition" (Sprugel 1991, Swetnam et al. 1999).

Not only is selecting a single temporal point inconsistent with the RV concept (Powell 2000), but choosing a single target condition (e.g., "50% of dry-forest sites should occur in the old forest single stratum (OFSS) structural stage") is also a misguided strategy because a range of conditions better reflects a dynamic equilibrium (e.g., "30-70% of dry-forest sites should occur in the OFSS stage").

Helping to identify opportunities to restore an ecosystem's resilience and integrity – its capacity for regeneration and renewal – is perhaps the most important contribution that RV information can offer to an assessment or planning effort. But this

recommendation presumes that past conditions and processes, as reflected by RV, provide appropriate context and guidance for management of contemporary ecological systems (Landres et al. 1999).

Even if land managers wish to turn the clock back to some nostalgic preconception of the presettlement era, our current reality of dams, roads, cities, fire suppression, climate change, and escalating human demands on natural resources would render this goal problematic. Clearly, we cannot turn our wheat fields back into properly functioning bluebunch wheatgrass steppes, no matter how inadequate they might now seem. We simply cannot go back in time and undo all that has happened and, in this sense at least, we are prisoners of our own history (Worster 1996).

A recent scientific assessment for the interior Columbia River basin suggests it would be difficult, if not impossible, to restore presettlement conditions for many portions of the western United States, even if this was an explicit policy objective (Quigley and Arbelbide 1997).

WHAT TIME PERIOD SHOULD RV REPRESENT?

Human history is dwarfed when compared with the Earth's geological history. When considering the vast changes occurring over geologic time, ecological history seems inconsequential. But ecosystems do change, albeit slowly. Some vegetation changes are so difficult for people to recognize that they have been referred to as the 'invisible present' (Magnuson 1990), evoking a perception of forest tranquility due to the seemingly timeless nature of large trees (Shugart and West 1981).

As commonly used in the interior Pacific Northwest, RV refers to a range of reference conditions existing prior to Euro-American emigration. This timeframe is often defined as the early to mid 1800s because it coincides with the Oregon Trail era when Euro-American influences began in the Blue Mountains (Evans 1991). It is also well aligned with contemporary climatic conditions, which have been in place for about 2,700 years (Mack et al. 1983).

The temporal baseline for which ranges are pertinent should be selected carefully to ensure it reflects presettlement conditions. This decision is easier for the western United States than for other areas because the West was settled relatively recently. In the British Isles, for example, the shieling system was a kind of mixed agriculture practiced in Scotland from prior to 1000 AD to the late 1700s, when it was largely abandoned due to poor harvests, famine, bouts of human disease, and a variety of other factors. Currently, only the occasional stone wall or drainage ditch provides clues that a widespread and relatively persistent pastoral society once existed in areas managed by using the shieling system (Holl and Smith 2007).

The Holl and Smith (2007) study provides a good example of potential pitfalls associated with establishing a temporal baseline for RV analyses. Any attempt to base historical ranges on conditions existing on Scotland's moors in the mid-1800s would need to account for the persistent ecological effects of a long-term human influence

reaching back almost a thousand years (the shieling system). Otherwise, it is likely that RV ranges would not reflect 'pristine' (non-anthropogenic) conditions if this were an explicit objective of adopting the RV concept (Holl and Smith 2007).

RV AND CLIMATE CHANGE

Substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and temperature (Milly et al. 2008). "Climate change suggests that planning must not depend on expectations that the past will provide a template for the future. But if not the past, then what? For the present, no one seems to know. Like the often-quoted investment advice, it now seems that past performance is no guarantee of future results" (deBuys 2008).

Some people believe that the presettlement era, which overlaps with a time period called the Little Ice Age (1300-1850), should no longer be used as a reference baseline because future conditions could be much warmer and drier than the mid-1800s due to climate change. Recent efforts to map changes in biophysical regimes for the United States, for example, found that half of the area could have shifts in moisture, temperature, and soil conditions such that it would be difficult to sustain 'historic' (presettlement) ecosystems there (Harris et al. 2006, Saxon et al. 2005).

Continuing with the RV approach, however, may still be the best option, as described here: "Some feel that HRV may no longer be a viable concept for managing lands in the future because of expected climate warming and increasing human activities across the landscape. Today's climates might change so rapidly and dramatically that future climates will no longer be similar to those climates that created past conditions. Climate warming is expected to trigger major changes in disturbance processes, plant and animal species dynamics, and hydrological responses to create new plant communities and alter landscapes that may be quite different from historical analogs" (Keane et al. 2009:1033-1034).

"At first glance, it may seem obvious that using historical references may no longer be reasonable in this rapidly changing world. However, a critical evaluation of possible alternatives may indicate that HRV, with all its faults and limitations, might be the most viable approach for the near-term because it has the least amount of uncertainty" (Keane et al. 2009:1034), particularly as compared to the uncertainty associated with the magnitude, timing, scale, and spatial extent of climate change impacts.

"Given the uncertainties in predicting climatic responses to increasing CO_2 and the ecological effects of this response, we feel that HRV time series derived from the past may have significantly lower uncertainty than any simulated predictions for the future. We suggest it may be prudent to wait until simulation technology has improved to include credible pattern and process interactions with regional climate dynamics and there has been significant model validation before we throw out the concept and application of HRV. In the meantime, it is doubtful that the use of HRV

to guide management efforts will result in inappropriate activities considering the large genetic variation in most species and the robustness inherent in regional landscapes that display the broad range of conditions inherent in HRV projections" (Keane et al. 2009:1034).

"Historical reference conditions remain useful to guide management because forests were historically resilient to drought, insects, pathogens, and severe wildfire. Adaptation of reference information to future climates is logical: historical characteristics from lower, southerly, and drier sites may be increasingly relevant to higher, northerly, and currently wetter sites" (Fulé 2008). "The study of past forest change provides a necessary historical context for evaluating the outcome of human-induced climate change and biological invasions. Retrospective analyses based on fossil and genetic data greatly advance our understanding of tree colonization, adaptation, and extinction in response to past climatic change" (Petit et al. 2008).

This section demonstrates that although the RV approach has recently been questioned, especially in the context of climate change, it is believed to function as a useful tool for informing management practices, rather than being used to set firm targets (Thompson et al. 2009) – RV is still useful for understanding the past in order to help manage ecosystems properly in the future (Swetnam et al. 1999). It also illustrates the importance of establishing a relevant reference period, which is the time period or era used to estimate the range of variation under historic disturbance regimes, including indigenous (American Indian) influences.

If using a historical reference period is problematic in a climate change context, then how might the RV concept be adapted to better reflect a 'future range of variation' consistent with projected warmer and dryer conditions? Three possible strategies for adapting the RV concept to be more compatible with future climate change could be considered:

1. When completing an RV analysis for a particular biophysical environment, use the RV ranges for one class warmer and dryer than the class being analyzed. This strategy is compatible with analyses involving relatively detailed stratifications (item #3 in the Project Planning and RV section discusses stratification). This strategy would not be appropriate for analyses involving potential vegetation groups (PVGs) because PVGs are too coarse to drop down by one class (i.e., it would not be appropriate to use Dry UF ranges for Moist UF acreage, or Moist UF ranges for Cold UF acreage). But if an RV analysis is completed at the plant association group (PAG) level, then this strategy might very well be appropriate (i.e., use Hot Dry UF ranges for Warm Dry UF acreage occurring in the analysis area).
2. Use existing RV ranges as a start-point, but then estimate departure from these initial conditions in response to climate change. Adopting this approach typically involves shifts in the ranges for a stratification class. If the RV range for ponderosa pine on Dry UF sites is 50-80% (table 3), and if this biophysical environment is expected to be warmer and dryer in the future, then the ponderosa pine range

might be modified to 60-90% to reflect increased habitat for ponderosa pine under future climates (or a range of 40-90% might be adopted to acknowledge that future climates may also be more variable than at present, so a range could be wider to account for vegetation conditions associated with increased variation).

3. Use state-and-transition modeling to prepare new RV ranges. This strategy involves making assumptions about the future abundance and representation of upland forest composition, structure, and density classes, and then loading the revised values into a state-and-transition model such as VDDT (see fig. 7, later). Simulations could then be completed to derive new RV ranges for each of the analysis categories (e.g., the composition, structure, and density classes).

ECOSYSTEM COMPONENTS ASSOCIATED WITH AN RV ANALYSIS

Vegetation reflects the integration of ecosystem components called composition, structure, and process (function); ecosystem components occur as multi-level hierarchies (table 1).

Composition refers to the relative abundance of ecosystem components such as water, nutrients, and species. Structure refers to the physical arrangement of composition in an ecosystem, and function refers to the processes through which composition and structure interact, including predation, decomposition, and disturbances such as wildfire (Aplet and Keeton 1999).

Table 1: Examples of forest ecosystem components, presented for three hierarchical levels.

COMPONENTS	ECOSYSTEM SCALE (HIERARCHICAL LEVEL) FINE	MID	BROAD
Composition	Individual tree	Cover type	Lifeform (tree/shrub/herb)
Structure	Tree size class	Structural stage	Physiognomic class
Process/Function	Photosynthesis	Disturbance	Climate

Sources/Notes: Although they are shown individually in this table, ecosystem components are interrelated – from an ecological perspective, they do not operate independently.

Species Composition

Composition refers to the kinds and numbers of organisms that make up an ecosystem (Manley et al. 1995). Depending on the hierarchical level being considered, forest composition includes individual trees, aggregations of tree species called cover types, or combinations of cover types called life forms (table 1).

Forest Structure

Structure includes the physical arrangement or spatial distribution of ecosystem composition (Manley et al. 1995). Structure occurs both horizontally (the spatial distribution of structure classes across an area) and vertically (trees of varying height growing in a multi-layered arrangement). Depending on the hierarchical level being

considered, examples of forest structure include size classes, structural stages, or physiognomic classes (table 1).

Process/Function

Processes are the flow or cycling or energy, materials, and nutrients through space and time (Manley et al. 1995). Forest processes include everything from photosynthesis and nutrient cycling to stand-initiating wildfires and climatic cycles (table 1). In the interior Pacific Northwest, disturbance processes have influenced forest vegetation conditions to a greater degree than other ecosystem processes (Clark and Sampson 1995, O'Hara et al. 1996, Oliver and Larson 1996).

Processes have an important influence on species diversity. Recent studies of British plants and birds found that different processes are likely to determine species diversity (biodiversity) at different spatial scales, and that the species richness pattern at a fine scale was statistically unrelated to the pattern at a coarse scale (Whittaker et al. 2001, Willis and Whittaker 2002).

CONDUCTING AN RV ANALYSIS

Apparently, there is no limit to the number of ecosystem characteristics that could be assessed by using the range of variation concept – Manley et al. (1995) identified more than 36 such characteristics (cobble embeddedness, etc.) and, in theory at least, all pertinent ecosystem metrics could be assessed and interpreted by using an RV approach (Egan and Howell 2001).

Broad-scale assessments completed for the Blue Mountains physiographic province and the interior Columbia River basin suggest that upland forest ecosystems could be characterized as healthy, sustainable, and resilient if three of their ecosystem components – species composition, forest structure, stand density – are within RV (Caraher et al. 1992; Gast et al. 1991; Lehmkuhl et al. 1994; Quigley et al. 1996; USDA Forest Service 2002).

It is recommended that an RV analysis for upland-forest biophysical environments include at least three ecosystem components: species composition, forest structure, and stand density.

RV results are typically presented for an entire analysis area, but they can also be reported for subdivisions (such as combinations of subwatersheds) when an analysis area is especially large. Subdivisions of a large watershed (fifth code hydrologic unit) or a subbasin (fourth code hydrologic unit) might be especially useful for supporting fine-scale project planning efforts.

Subdividing an RV analysis area into smaller units must be done carefully. Some areas have a strong elevational gradient resulting in equivalent proportions of biophysical environments (Desolation Creek watershed on the North Fork John Day Ranger District is an example of this situation). If not done carefully, subdividing these areas can essentially disrupt this equivalence, resulting in inconsequential or

minor amounts of one or more biophysical environments, in which case it might be advisable to conduct an RV analysis for the whole area as one integrated unit.

The results of an RV analysis are generally presented in a table showing the existing percentages and RV percentages for each ecosystem component, and stratified using categories of potential vegetation such as potential vegetation groups (PVG).

Project Planning and RV

When a vegetation management project is proposed for implementation on National Forest System lands, an interdisciplinary planning process must be completed before any ground-disturbing activities can occur. When a proposed project involves modifications to an area's existing complement of vegetation cover types, forest structural stages, or stand density classes, then:

- The planning process should include an RV analysis (according to the Forest Plan amendment referred to as the Eastside Screens, an RV analysis must be completed if the proposed project includes a timber sale).
- The planning documentation should disclose how RV results were used to identify which of the existing cover types, structural stages, or density classes are proposed for treatment.

This section is a primer about fundamental vegetation planning concepts and principles. An RV analysis will typically be completed at several points in the vegetation planning process; this section identifies when those points occur, and it provides my thoughts about incorporating RV analysis into the overall project planning process for integrated vegetation treatments.

1. **Before initiating a planning process, an analyst should develop an understanding of reference conditions for ecosystem components in the planning area** (e.g., soil conditions, animal population sizes, plant species or seral stage composition, stream sediment loads, air quality, forest structural stages, etc.). Developing an awareness of reference conditions is best accomplished by consulting historical data sources, particularly maps depicting species composition, forest structure, stand density, and disturbance events.
   (a) The Umatilla National Forest made significant investments over the last 20 years to locate and digitize relevant historical mapping, including maps derived from General Land Office survey notes collected in the 1880s (Powell 2008); thematic maps depicting forest conditions in 1900, 1914-16, 1935-36, 1953-60, and 1987-88 (Powell 2009c); and topical maps portraying wildfires, insect outbreaks, and other disturbance processes (Powell 2009b, 2009c). Disturbance mapping is particularly valuable for understanding the ecological processes responsible for creating forest composition, structure, and density.

2. **Use an appropriate size of planning (analysis) area**.
   (a) It is recommended that an RV analysis be conducted for land areas no smaller than 15,000 to 35,000 acres (this recommended size range was taken from the May 1994 Environmental Assessment for the Eastside Screens).

(b) Areas larger than 35,000 acres are appropriate and preferable for an RV analysis; areas smaller than 15,000 acres should be avoided since vegetation patterns might not be consistent with those created by the historical disturbance regimes of the analysis area.

(c) The Fire Regime Condition Class (FRCC) assessment system (Barrett et al. 2010) is used to characterize fire regimes and understand their departure from historical reference conditions. FRCC uses many of the same concepts and tools (such as the Vegetation Dynamics Development Tool) as the range of variation. The Pacific Northwest Regional Office (R.O.) has the following scale recommendations for FRCC analyses, and they are based on grain (resolution) considerations related to typical patch-size variation by fire regime group. Here are the R.O.'s recommendations:

Fire Regime Group	**Suggested Hydrologic Unit Code**
I/II (Low/mixed severity)	HUC6 (subwatershed)
III (Mixed/low severity)	HUC5 (watershed)
IV/V (Replacement severity)	HUC4 (subbasin)

3. **Stratify the vegetation data into potential vegetation groups**.

(a) An RV analysis relies on a consistent stratification of potential vegetation. Before conducting an RV analysis, the planning area acreage should be stratified into potential vegetation groups (PVG)[5]. Generally, a potential vegetation type (ecoclass) code is available for each polygon in an analysis database, and a cross-walk process can be used to assign PVG by using the ecoclass code (cross-walk tables are provided as tables 8-9 in Powell et al. 2007).

(b) PVG information for the Blue Mountains is provided in a report entitled "Potential vegetation hierarchies for the Blue Mountains section of northeastern Oregon, southeastern Washington, and west-central Idaho" (Powell et al. 2007). Copies of this report are available from the Pacific Northwest Research Station website (http://www.treesearch.fs.fed.us/pubs/27598).

(c) **If less than 1,000 acres of a PVG occurs in a planning area, it should be ignored during analysis** because a full complement of cover types, structural stages, or tree density classes would not be expected for such a small amount of acreage. If a PVG has less than 1,000 acres in a planning area, do not add its acreage to another PVG because it is not appropriate to combine ecosystem components (vegetation cover types, forest structural stages, stand density classes) produced by different disturbance regimes.

4. **Classify existing vegetation information into the same analysis categories included in tables 2, 3, 5, and 7**, all of which qualify as derived attributes

[5] Potential vegetation types (PVTs) are often aggregated into higher-level groups for landscape-scale analysis. Generally, PVTs are aggregated into plant association groups (PAGs) or potential vegetation groups (PVGs). Analysts recently settled on PVG as an ideal aggregation unit because standards and guidelines in the revised Forest Plan (currently in draft form) are stratified by PVG, and because PVGs are assumed to better reflect broad-scale disturbance processes influencing composition, structure, and density.

because they are calculated (not measured) by using a combination of metrics from stand examination or photo interpretation surveys. White papers describe how the derived fields are calculated, as demonstrated by using three examples:

(a) Forest species composition is characterized by using a derived field called vegetation cover type (table 2). Vegetation cover types are calculated by using a three-step process described in Powell (2004: page 14).

(b) Forest structure is characterized by using a derived field called forest structural stage (tables 3-4). Forest structural stages are calculated by using a process described in Powell (2004: pages 11-12 and 33-34) as the first option, or in Powell (2009a: table 3 on page 6) as the second option.

(c) Tree density is characterized by using a derived field called stand density class (table 5). Stand density classes are calculated from tabular information presented in Powell (2009d: pages 9-13 in that source provide calculation information by PVG).

5. **Calculate existing amounts of the analysis categories** (such as cover type, structural stage, tree density class) for the analysis area, as stratified by PVG, and convert the acreage for each category into its corresponding percentage value. A spreadsheet will be helpful for this task (fig. 4).

   The calculation methodology is simple and straightforward – the acreage for a particular category (such as the stem exclusion or SE structural stage in fig. 4), by PVG, is divided by total acreage for the component – 3,200.9 acres of SE divided by 11,503.4 acres total = 27.8 or 28% (see fig. 4).

6. **Widespread utilization of geographic information system (GIS) technology** allows land managers to gain access to a wide variety of spatially-explicit information about ecological site conditions, mensurational stand metrics, land use allocations, and operability or implementation considerations. GIS allows grouping of forest stands into strata according to land allocations, site characteristics, ecological site potentials, and any number of other criteria (Horning et al. 2010).

   GIS technology is helpful for completing the stratification processes described in step 3 (PVG) and in this step, where stands with similar characteristics are being grouped into the same classes by using composition, structure, or density.

7. **Determine whether current conditions are within or outside of their range of variation** (see fig. 1) by comparing the calculated existing percentage with the RV percentage ranges for each analysis category.

   (a) RV analysis results are typically provided in a table where existing amounts (expressed in acres and as a percentage) are presented for each ecosystem component (cover type, structural stage, and density class), along with their corresponding RV ranges, and all tabular results are reported by PVG. Table 2 provides an example of the tabular presentation format.

Moist Upland Forest PVG:							
Struc Stage	Acres	Combined Stage	Combined Acres	Current Percent	Lower RV Limit	Upper RV Limit	Interpretation
BG	0.0	SI	397.5	3%	20%	30%	Well below RV
SI	397.5						
SEOC	1,913.0	SE	3,200.9	28%	20%	30%	Within RV
SECC	1,287.9						
UR	3,507.1	UR	3,816.3	33%	15%	25%	Above RV
YFMS	309.2						
OFMS	1,079.8	OFMS	1,079.8	9%	15%	20%	Below RV
OFSS	3,008.9	OFSS	3,008.9	26%	10%	20%	Above RV
Total	11,503.4		11,503.4				

Figure 4 – Example spreadsheet format for completing RV calculations. In this example, the database included eight structural stages from O'Hara et al. (1996) (Struc Stage column; BG = bareground; SI = stand initiation; SEOC = stem exclusion open canopy; SECC = stem exclusion closed canopy; UR = understory reinitiation; YFMS = young forest multi-strata; OFMS = old forest multi-strata; OFSS = old forest single stratum). Forest direction is to use five stages (Martin 2010), so some of the O'Hara et al. (1996) stages must be combined before completing an RV analysis for project planning. The BG and SI stages are combined into an SI stage, the SEOC and SECC stages are combined into an SE stage, and the UR and YFMS stages are combined into an UR stage (see the Combined Stage column). The Combined Acres, Current Percent, Lower RV Limit, and Upper RV Limit columns pertain to the collapsed (combined) structural stages. The current percentage of each stage is compared to the historical range (Lower and Upper RV Limit columns) to derive an RV result (Interpretation column).

Table 2: RV results for the moist forest PVG in a project planning area.

Structural Stage	Historical Range Percent	Historical Range Acres	Current Amount Percent	Current Amount Acres	HRV Interpretation	Screens Interpretation
Stand initiation	20-30	2300-3430	3	400	Below RV	
Stem exclusion	20-30	2300-3430	28	3200	Within RV	
Understory reinitiation	15-25	1715-2865	33	3820	Above RV	
Old forest SS	10-20	1150-2300	26	3010	Above RV	**Scenario A**
Old forest MS	15-20	1715-2300	9	1080	Below RV	

Notes: the Screens Interpretation column shows how the HRV interpretation results (e.g., above/within/below RV) for Old Forest were used to identify whether forested lands within the biophysical environment need to comply with Scenario A or Scenario B from the Wildlife Screen portion of the Eastside Screens (Regional Forester's Forest Plan Amendment #2) (USDA Forest Service 1995).

(b) A tabular presentation format is not required, however, and some analysts prefer to portray the results graphically by using shaded boxes to depict the historical range values, and a large dot, star, or another symbol to denote the existing percentage. Figure 5 provides an example of the graphical presentation format; the figure includes the same data, in terms of historical ranges (gray vertical bars) and current percentages (square black markers), as is presented in the table above.

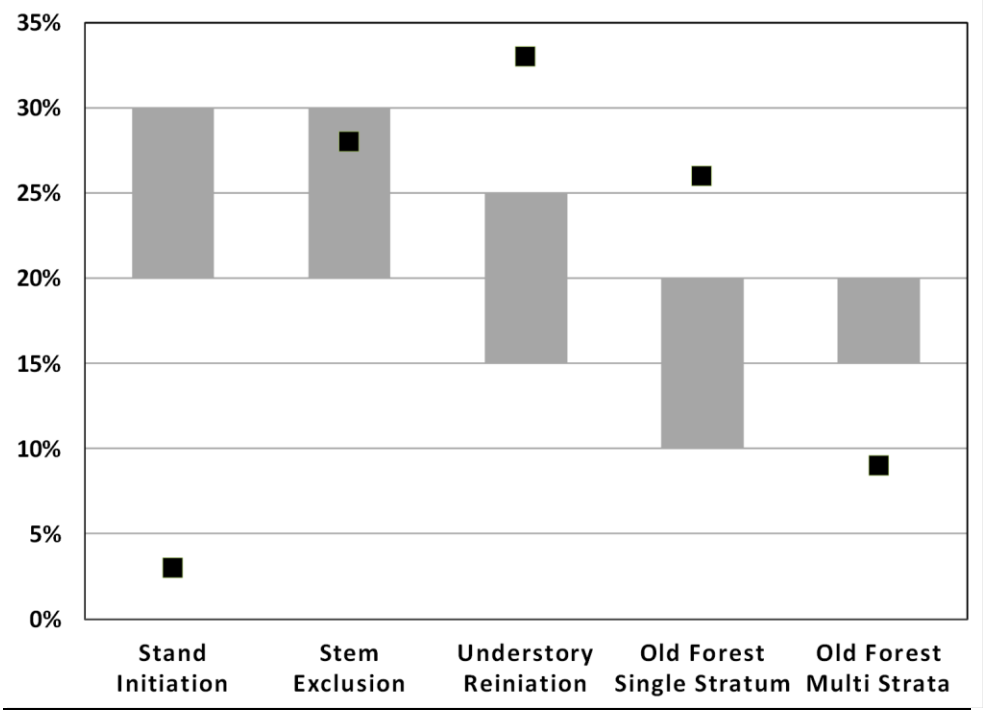


Figure 5 – RV results for a forest structural stage analysis, presented graphically in chart format in lieu of the tabular summary provided on the previous page. Note that the percentage values shown here, both for the historical ranges and the current amounts, are the same as for the table on page 20. Gray bands are historical ranges; black markers show current percentages.

8. **In a typical planning context, the RV analysis described to this point is completed during what is termed a NFMA (National Forest Management Act) or Plan Consistency, plan-to-project, proposal development, or 'left side of the triangle' process (fig. 6) (all of these terms pertain to the same portion of the Forest Service planning model depicted in fig. 6)**.
   (a) A NFMA analysis is designed to examine the existing conditions in a planning area, compare them with a reference condition (such as RV ranges) or a desired future condition, and then determine if differences between existing and reference or desired conditions warrant active management intervention. If the difference between existing and reference conditions is substantial for a particular analysis indicator (such as the old forest structural stage), then the difference may qualify as a purpose and need to modify some of the existing condition in such a way as to move it closer to the reference condition.

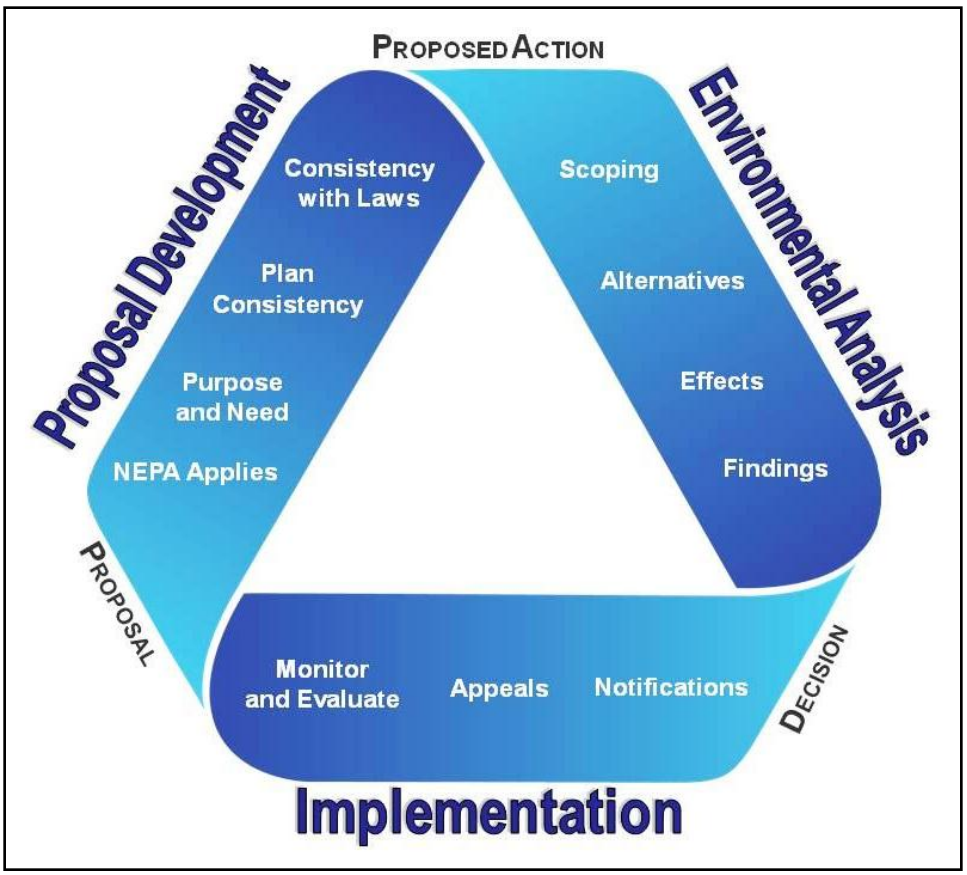


Figure 6 – The Forest Service planning model (also known as the NEPA triangle). RV analyses are used extensively during what is termed a NFMA or Forest Plan consistency evaluation, proposal development, or 'left side of the triangle' process. RV analyses are also utilized during the environmental analysis (right side of the triangle) portion of the planning model.

(b) If a NFMA analysis suggests that active management is warranted to address over- or under-representation of a particular ecosystem component (such as old forest), then the NFMA results from this 'left side of the triangle' process provide the rationale for a Purpose and Need statement, which is then used to formulate a Proposed Action when a NEPA process ('right side of the triangle') is initiated. You could think about this way: the NFMA analysis identifies the 'problem,' which is stated as a Purpose and Need, and the Proposed Action identifies the agency's preferred 'solution' to the problem.

(c) RV results are often provided as issues or needs when formulating a Purpose and Need. In some instances, an issue or need is stated in general terms (a specific condition is over- or under-represented, for example). In other cases, an issue or need is stated in quite a bit of detail (at least X acres of condition Y needs to be transformed to condition Z in order to bring condition Z (and possibly condition Y as well) within their RV). Often, a unit's environmental coordinator will specify whether they prefer the general or quantified approach. Here is an issue or need statement stated in more general terms:

Issue: Existing tree species composition is not within its range of variation.

1. On dry-forest sites, the ponderosa pine forest cover type is under-represented (below RV); the Douglas-fir and grand fir cover types are over-represented (above RV).
2. On moist-forest sites, the Douglas-fir, western larch, broadleaved trees, and lodgepole pine forest cover types are under-represented; the grand fir and spruce-fir cover types are over-represented.

(d) NFMA results are almost always addressed by using the NEPA process, regardless of which management activities (prescribed fire, timber sale, stewardship harvest, etc.) are being considered as proposed actions in response to the NFMA results; it would be very unusual to be able to address NFMA results without using NEPA.

9. Question: **Why use an RV analysis or another NFMA process to justify a vegetation management project? Why not use the Forest Plan instead?**
Answer: *The Land and Resource Management Plan does not compel action, it just authorizes it*.
This means that a compelling need for active management to modify existing vegetation conditions must come from a source other than the Forest Plan.

10. Another Common Question: **Instead of conducting an RV analysis, why can't I use a broad-scale assessment completed for the Blue Mountains as justification for completing a vegetation management project?**

(a) Many scientifically rigorous reports provide broad-scale context for Blue Mountains vegetation management issues, including the following items:

- Blue Mountains forest health report (Gast et al. 1991).
- "Restoring ecosystems in the Blue Mountains" (Caraher et al. 1992).
- "Forest health science perspectives" reports (Johnson 1994, Mutch et al. 1993, Tanaka et al. 1995, and Wickman 1992 are useful vegetation management sources).
- Reports produced for the Eastside forest ecosystem health assessment (Agee 1994, Everett 1994, Everett et al. 1994, Harvey et al. 1994, Hessburg et al. 1994, Huff et al. 1995, Jensen and Bourgeron 1994, Johnson et al. 1994, Lehmkuhl et al. 1994, Oliver et al. 1994, and Robbins and Wolf 1994 are useful vegetation management sources).
- Eastside forests scientific society panel report (Henjum et al. 1994).
- Eastside forest science panel review of eastern Oregon timber harvest practices (Johnson et al. 1995).
- Reports produced for the Interior Columbia Basin Ecosystem Management Project (Hessburg et al. 1999b,c,d; Quigley and Arbelbide 1997; and Quigley et al. 1996 are useful vegetation management sources).

(b) These broad-scale reports provide valuable context for a scale above your planning area. They can address questions like these: Is a situation indicat-

ing a purpose or need for action – the existence of high amounts of overstocked forest on dry sites – common across the Blue Mountains, or is it specific to just your planning area? The reports can answer the first question (is a situation common across the whole Blues?), but an RV or NFMA analysis must be used to answer the second question (is a situation specific to just your planning area, or does it occur in the planning area at a lesser or greater magnitude than for the whole Blues?). But, broad-scale context cannot be used as the sole justification for proposing vegetation management treatments because it is not site specific – the broad-scale reports cited above pertain to the whole Blue Mountains (or even larger areas), so they are too general to provide site-specific information for your planning area.
Broad-scale reports are valuable for explaining to the reader if your RV results are typical for the higher-level context in which the planning area occurs (is old forest deficient for the basin?), ***but they cannot substitute for actually completing an RV analysis for a specific planning area***.

(c) There may be one exception to this situation, however. Ecosystem analysis at the watershed scale (EAWS) is considered to be a mid-scale process; it has been completed for some portions of the Umatilla National Forest, and it typically includes RV analyses for composition, structure, and density. Many of the RV analyses completed during EAWS were completed at the subwatershed scale (HUC6), and since it is common practice on the Umatilla NF to combine several adjoining subwatersheds when establishing a planning area boundary, then it may be possible to extract the RV analyses for appropriate subwatersheds from an EAWS report and use them to identify issues, concerns, and opportunities for a planning area.

(d) Lacking an EAWS, an RV analysis must be used to characterize existing conditions of your planning area, and to put them in a meaningful context by comparing them against a baseline reference condition.

11. Use a database analysis to help determine where current conditions depart from RV. A database analysis helps prioritize potential treatment areas (which polygons have the highest priority for active management?), and it can help answer the "why here, why now" NEPA imperative (e.g., it can help provide spatial and temporal context for vegetation treatments).

(a) Generally, the database analysis portion of project planning will work through a series of filters or sieves, ranging from most restrictive to least restrictive. The first sieve almost always involves Forest Plan management allocations because their direction (standards, guidelines) dictates the treatments that can, or cannot, be considered for implementation on lands assigned to the management area. Some of the Forest Plan management allocations allow timber management practices to occur (forest lands in these allocations are classified as 'suitable lands,' and they have what is referred to as 'scheduled harvest' in the Forest Plan), whereas others are classified as unsuitable and timber management is prohibited.

(b) *A timber sale cannot be used in unsuitable management areas to address a purpose and need for action (addressing an over- or under-representation of certain structural stages, for example) unless the project's NEPA documentation includes a site-specific Forest Plan amendment to make timber management permissible in this instance*.

Note: Forest Plan context varies by treatment activity. Many Forest Plan management allocations prohibiting timber management are suitable for prescribed fire. So even when vegetation management objectives cannot be addressed by using timber management activities, prescribed fire can almost always be considered *if it could accomplish them effectively*.

(c) After working through the Forest Plan sieve, other filters would then be applied. Some of these filters deal with operational considerations – can a polygon be accessed from the existing transportation system, or would new road developments be required? Does the polygon contain lands whose slope gradients allow implementation of a relatively low-cost yarding (logging) system, or would slope gradients or a lack of road access require a high-cost option such as skyline or helicopter yarding?

(d) After evaluating suitability, operational, and logistical filters, the next steps typically involve resource-based considerations such as wildlife habitat connectivity or soil/water protections: Does the polygon occur in a wildlife connectivity corridor, or in an area where previous management activity has resulted in more than 15% detrimental soil disturbance?

12. **Consider how ecosystem components interact** (is the OFSS structural stage associated mostly with the ponderosa pine (PP) forest cover type?), and use these insights about interactions to identify opportunities to address needs related to more than one component with a single vegetation treatment. For the best-case scenario, could a single treatment address composition, structure, and density simultaneously?

(a) After removing forest polygons on unsuitable lands or with other issues or concerns from further consideration (step #11), a multi-factor process is then used to identify which of the remaining polygons could be treated in such a way as to address several needs simultaneously.

An example: Let's assume that an RV analysis found the Dry Upland Forest PVG in a planning area to have an over-representation of the OFMS structural stage, the Douglas-fir cover type, and the high stand density class, and an under-representation of the OFSS structural stage, the ponderosa pine cover type, and the low stand density class. Now, let's further assume that the planning area's vegetation database has 95 polygons with a cover type code of mix-PSME (mix-Douglas-fir), a structural stage code of OFMS (old forest multi-strata), and a density class code of H (High). Further inspection of the data suggests that many of the mix-PSME polygons contain some amount of ponderosa pine stocking, even though it is not the plurality tree species (if it had been, then the polygon would have been classed as mix-

PIPO). At this point, you realize it might be possible to prescribe one cutting method for these polygons (such as improvement cutting or free (proportional) thinning) and have their post-treatment composition, structure, and density all meet the RV objectives – after implementing the treatment, you believe they would classify as PIPO or mix-PIPO (ponderosa pine) cover type, OFSS (old forest single stratum) structural stage, and Low stand density class. Thus, prescribing one treatment method for these 95 polygons would reduce over-represented components (mix-PSME, OFMS, and H density) and simultaneously increase under-represented components (ponderosa pine, OFSS, and L density).

Bottom Line: These polygons would be your first priority for additional analysis because treating them would address all three upland forest components concurrently: species composition, forest structure, and stand density.

(b) Not all of the high-priority polygons would necessarily be included in the project's proposed action alternative because some of them might be 'discarded' for other reasons – they are too far from a road to be economically viable, they are on steep slopes and the logging system would be too costly for the small amount of volume removed, and so forth. But as described above in step #11, you generally would have already applied operational and logistical filters by this point in the planning process, in which case you can be confident (within the accuracy of your polygon data) that the high-priority polygons are truly available for active management. It would be more common to drop polygons from further consideration due to interdisciplinary concerns – the stands may be located in a wildlife connectivity corridor, they may be providing crucial elk hiding or security cover, etc.

13. **From a temporal standpoint, consider an area's recent disturbance history** and then decide if an RV analysis is appropriate at this time. For example, an RV analysis was not completed when conducting an ecosystem analysis at the watershed scale (REO 1995) for the Tower Fire (Powell 1997), primarily because much of the 52,000-acre assessment area had just experienced uncharacteristic fire effects (more stand-replacing severity than is typical for fire regime 1), so resulting composition, structure, and density did not reflect a dynamic equilibrium created by properly functioning disturbance regimes (and in this instance, RV analysis was particularly inappropriate because the assessment area included only the fire extent).

USING RV TO EVALUATE SPECIES COMPOSITION

Plant species occur in either pure or mixed communities called cover types. Tree species occurrence in a project planning or analysis area can be characterized by using cover types, a classification of existing vegetation composition (Eyre 1980, Shiflet 1994). Cover type codes reflect majority or plurality tree species abundance, and they apply to both pure and mixed stands.

RV information for species composition is expressed for vegetation cover types, and it is derived primarily from Vegetation Dynamics Development Tool) modeling completed for Blue Mountains ecosystems (fig. 7). Range of variation information for vegetation cover types is stratified by upland-forest potential vegetation group and provided in table 3.

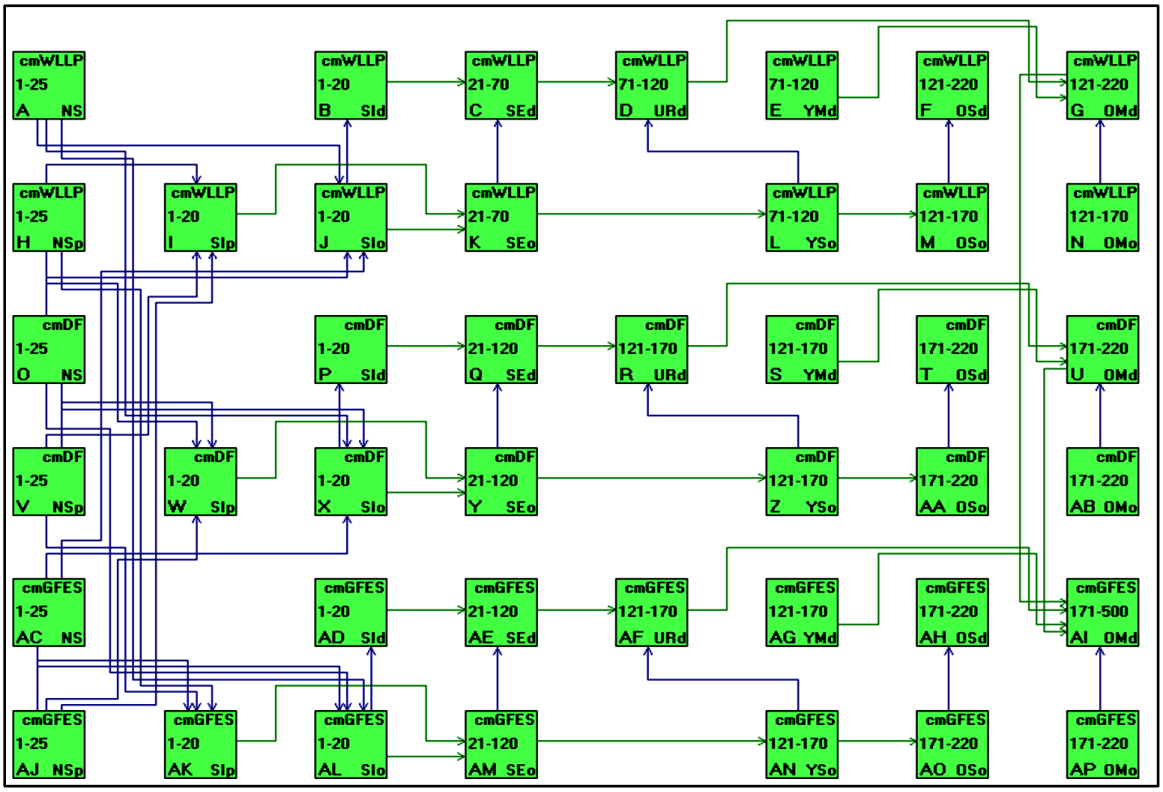


Figure 7 – Schematic (akin to a wireframe diagram or circuit board) from the VDDT model showing vegetation cover type states (green boxes) and transitions (colored arrows) for the cool moist (cm) upland forest plant association group. Similar vegetation cover type diagrams (models) exist for other plant association groups, and for various combinations of forest structural stages and stand density classes. VDDT modeling was used to generate RV information for most of the vegetation standards and guidelines contained in revised Forest Plans for the Blue Mountains national forests (Forest Plan revisions are still in draft form and have not yet been approved).

VDDT is in a class of models designed to examine vegetative change for landscape-scale planning (Barrett 2001). It has been used to estimate vegetation conditions in support of Forest Plan revision (Merzenich and Frid 2005), to examine interactions between vegetation conditions and wildlife habitat (Shifley et al. 2008), to predict changes for ecosystems of special concern such as quaking aspen (Strand et al. 2009), and to support broad-scale fire regime analyses (Swetnam and Brown 2010).

Table 3 expresses the percentage of a landscape (preferably at least 15,000-35,000 acres in size) occupied by various vegetation cover types (ponderosa pine, grand fir, etc.). A cover type may have a majority of one species (e.g., grand fir comprises more than 50% of stocking, coded as ABGR); if less than 50% of a species is predominant, then a cover type is named for the species comprising a plurality of stocking (grand fir comprises less than 50% of stocking, coded as mix-ABGR).

Table 3: Range of variation information for species composition (vegetation cover types), expressed as percentages by potential vegetation group.

Vegetation Cover Type[1]	POTENTIAL VEGETATION GROUP (PVG)		
	Dry UF	Moist UF	Cold UF[2]
	Range of Variation (Percentage)		
Grass-forb	0-5	0-5	0-5
Shrub	0-5	0-5	0-15
Western juniper	0-5	0	0
Ponderosa pine	50-80	5-15	0-5
Douglas-fir	5-20	15-30	5-15
Western larch	1-10	10-30	5-15
Broadleaved trees	0-5	1-10	0-5
Lodgepole pine	0	25-45	25-45
Western white pine	0-5	0-5	0
Grand fir	1-10	15-30	5-15
Whitebark pine	0	0	0-10
Subalpine fir and spruce	0	1-10	15-35

Source/Notes: Derived from state-and-transition modeling by using the Vegetation Dynamics Development Tool (VDDT). Potential vegetation group is described in Powell et al. (2007); UF = Upland Forest.

[1] Cover types reflect the existing vegetation composition of a polygon (Eyre 1980, Shiflet 1994). Cover type codes are described in Powell (2004); cover types consist of these coding combinations:

Grass-forb: all grass and forb codes
Shrub: all shrub codes
Western juniper: JUOC and mix-JUOC
Ponderosa pine: PIPO and mix-PIPO
Douglas-fir: PSME and mix-PSME
Western larch: LAOC and mix-LAOC
Lodgepole pine: PICO and mix-PICO
Western white pine: PIMO and mix-PIMO
Grand fir: ABGR and mix-ABGR
Whitebark pine: PIAL and mix-PIAL
Broadleaved trees: POTR, POTR2, mix-POTR, and mix-POTR2
Subalpine fir and spruce: ABLA, PIEN, mix-ABLA, and mix-PIEN

[2] When a vegetation cover type has a zero in a PVG column (not zero as the lower limit of a range – just zero by itself), it means that the cover type is not believed to have existed historically in that particular biophysical environment.

Note: It is important to emphasize that the cover type information shown in table 3 does NOT pertain to the species composition of an individual stand or polygon. In other words, the species composition of a typical moist-forest stand would not be expected to consist of 5-15% ponderosa pine, 15-30% Douglas-fir, and so forth – these species ranges, taken from table 3, refer to the percentages of a moist-forest **landscape** supporting ponderosa pine cover types, Douglas-fir cover types, and so forth.

USING RV TO EVALUATE FOREST STRUCTURE

Oliver and Larson (1996) developed a forest structure classification system involving four structural stages (table 4). Oliver and Larson's (1996) classification system works well for conifer forests located west of the Cascade Mountains, but it was not perceived to adequately represent the full spectrum of structural conditions for the interior Pacific Northwest, where forest structure is more varied. Therefore, the Oliver and Larson (1996) system was expanded to seven classes to encompass more structural variation (O'Hara et al. 1996).

When the Pacific Northwest Region of the USDA Forest Service issued two versions of a Regional Forester's Forest Plan Amendment referred to as the Eastside Screens between 1993 and 1995 (USDA Forest Service 1994, USDA Forest Service 1995), it established a procedural requirement to use RV as an analytical technique by comparing the current percentage of each forest structural stage with its historical range.

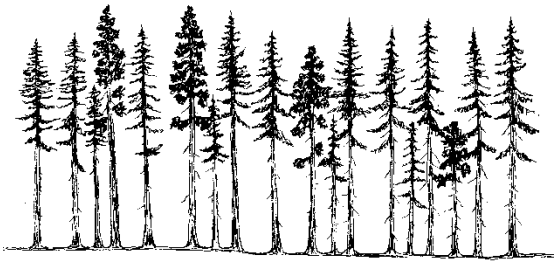
After fire suppression allowed interior Douglas-fir and grand fir to invade dry-forest sites because surface fire was prevented from fulfilling its role as a tree-thinning process, vertical forest structure was transformed when leaf area (foliage biomass) shifted downward from one high canopy layer (such as the old forest single stratum structural stage) to multiple lower layers (such as the understory reinitiation stage) (Agee 1996; Arno et al. 1995; Brown et al. 2003; Graham et al. 1999, 2004).

The transformation of vertical forest structure is an important issue because it created understory layers functioning as ladder fuel, increasing the probability that surface fire would transition to crown fire (Fiedler et al. 2004, Graham et al. 2004, Mason et al. 2003, Peterson et al. 2005, Stephens 1998). For this reason, forest structure is typically included in a fuels analysis to assess ladder-fuel changes through time.

RV estimates for forest structural stages, as derived from state-and-transition modeling by using the Vegetation Dynamics Development Tool (VDDT), were compared with other RV sources to determine if the VDDT values are consistent with what has been traditionally used for the Blue Mountains during the last 20 years.

The structural-stage comparison focused on the abundance of old-forest (late-old) structure by potential vegetation group. The other sources found that the estimated RV for historical levels of old forest on dry upland sites in the Blue Mountains varied from 10 to 80%; the VDDT estimate of 45-75% is within this range. The other sources found that the estimated RV for historical levels of old forest on moist upland sites in the Blue Mountains varied from <10 to 60%; the VDDT estimate of 25-40% is within this range (Countryman and Justice 2010).

Table 4: Description of forest structural stages.

	**Stand Initiation (SI)**. Following a stand-replacing disturbance such as wildfire or tree harvest, growing space is occupied rapidly by vegetation that either survives the disturbance, or colonizes the area afterward. Survivors survive the disturbance above ground, or they initiate new growth from underground organs or from seeds on the site. Colonizers disperse seed into disturbed areas, it germinates, and then new plants establish and develop. A single canopy stratum of tree seedlings and saplings is present in this stage.
	**Stem Exclusion (SE)**. In this single-cohort stand structure, trees initially grow fast and quickly occupy all of their growing space, competing strongly for sunlight and moisture. Because trees are tall and reduce subcanopy light levels, understory plants (including smaller trees) are shaded and grow more slowly. Species needing sunlight usually die; shrubs and herbs may go dormant. In this stage, establishment of new trees is precluded by a lack of sunlight (stem exclusion closed canopy) or soil moisture (stem exclusion open canopy).
	**Understory Reinitiation (UR)**. As the forest develops, a new age class of trees (cohort) eventually gets established after overstory trees begin to die, or because they no longer fully occupy their growing space. This period of overstory crown shyness occurs when tall trees abrade each other in the wind (Putz et al. 1984). Regrowth of understory seedlings and other vegetation then occurs, and trees begin to stratify into vertical layers. This stage consists of overstory trees at a low to moderate density, with small trees underneath.
	**Old Forest (OF)**. Many age classes and vegetation layers mark this structural stage containing large, old trees. Snags and decayed fallen trees may also be present, leaving a discontinuous overstory canopy. The drawing shows a single-layer stand of ponderosa pine reflecting the influence of frequent surface fire on dry-forest sites (old forest single stratum; OFSS). Surface fire is not common on cold or moist sites, so these environments generally have multi-layer stands with large trees in the uppermost stratum (old forest multi strata; OFMS).

Sources/Notes: Based on O'Hara et al. (1996), Oliver and Larson (1996), and Spies (1997). Note that O'Hara et al. (1996) also included a young multi-strata stage, which is not included here (although it could be viewed as a variant of understory reinitiation). The Eastside Screens (USDA Forest Service 1995) refers to the old-forest stages as 'multi-stratum, with large trees,' and 'single stratum, with large trees.'

When Blue Mountain VDDT results for structural stages were compared with other sources providing structural stage information for the Blue Mountains, the other sources used for the comparison are:

- Caraher Report (Caraher et al. 1992).
- Eastside Forest Ecosystem Health Assessment (Lehmkuhl et al. 1994).
- Eastside Forests Scientific Society Panel (Henjum et al. 1994).
- Ecosystem components assessment for the Interior Columbia Basin Ecosystem Management Project (ICBEMP) (Quigley and Arbelbide 1997).
- Landscape-level comparison of historical and current conditions for ICBEMP area (Hessburg et al. 1999b).
- Terrestrial vertebrate source habitats for ICBEMP area (Wisdom et al. 2000).
- Historical RV estimates for central Idaho (Morgan and Parsons 2001).
- Analysis of pre-management era patterns of forest structure for mixed-conifer forests (Hessburg et al. 2007).
- Simulation modeling for the upper Grande Ronde River sub-basin (INLAS project) (Hemstrom et al. 2007).
- Fire and fuel model scenario planning for northeast Oregon (Wales et al. 2007).

As an example of the comparison process, Hemstrom et al. (2007) used VDDT to simulate landscape composition for dry upland forests under a natural fire regime. They found that the mean percentage of forested land in the old forest single stratum structural stage was just under 20%, whereas the mean percentage in the old forest multi-strata structural stage was less than 5%. When Wimberly and Kennedy (2008) completed a similar modeling exercise for warm dry forests of the Blue Mountains, they found that about 15% was in the old forest single stratum structural stage, and 4% was in the old forest multi-strata structural stage.

RV information for forest structure is expressed for forest structural stages, and it is derived from VDDT (Vegetation Dynamics Development Tool) state-and-transition modeling completed specifically for Blue Mountain ecosystems (see fig. 7 for an example of VDDT modeling). Range of variation information for forest structural stages, as stratified by potential vegetation group, is provided in table 5.

Table 5: Range of variation information for forest structural stages, expressed as percentages by potential vegetation group.

	FOREST STRUCTURAL STAGE				
Potential Vegetation Group	**SI**	**SE**	**UR**	**OFSS**	**OFMS**
	Range of Variation (Percentage)				
Cold Upland Forest	20-45	10-30	10-25	5-20	10-25
Moist Upland Forest	20-30	20-30	10-20	10-20	15-20
Dry Upland Forest	15-25	10-20	5-10	40-60	5-15

Source/Notes: Derived from state-and-transition modeling by using the Vegetation Dynamics Development Tool (VDDT). Potential vegetation group is described in Powell et al. (2007). Forest structural stages are described in table 4.

USING RV TO EVALUATE STAND DENSITY

Stand density is a characterization of tree stocking for an area. It expresses the number of tree stems occupying a unit of land. Stocking can be expressed as a 'stand density index' or in some other measure of relative density, or it can be quantified in absolute terms as a number of trees per acre or as the amount of basal area, wood volume, or canopy cover on an area (Powell 1999).

Published stocking guidelines are available for evaluating stand density levels (Cochran et al. 1994; Powell 1999, 2009d). By using the stocking guidelines in conjunction with potential vegetation groups, it is possible to estimate how much forestland acreage is currently overstocked, and how it compares to a range of variation for this ecosystem component.

RV information for stand density is expressed for stand density classes, and it is derived from VDDT (Vegetation Dynamics Development Tool) state-and-transition modeling completed specifically for Blue Mountain ecosystems (see fig. 7 for an example of VDDT modeling). Range of variation information for stand density classes, as stratified by potential vegetation group, is provided in table 6.

Table 6: Range of variation information for stand density classes, expressed as percentages by potential vegetation group.

Stand Density Class (expressed as basal area, in ft^2/acre at 10'' QMD)	**Potential Vegetation Group**		
	Dry UF	**Moist UF**	**Cold UF**
	Range of Variation (Percentage)		
Low (dry: <55; moist: <100; cold: <80)	40-85	20-40	15-35
Moderate (dry: 55-85; moist: 100-150; cold: 80-120)	15-30	25-60	20-40
High (dry: >85; moist: >150; cold: >120)	5-15	15-30	25-60

Source/Notes: Derived from Powell (2009d). Potential vegetation group is described in Powell et al. (2007). QMD is quadratic mean diameter. The basal area values in this table are derived from weighted-average stand density index stocking levels pertaining to mixed-species, even-aged stands – Dry UF assumes a species mix of 70% ponderosa pine, 20% Douglas-fir, and 10% grand fir; Moist UF assumes a species mix of 30% Douglas-fir, 20% western larch, 20% lodgepole pine, and 30% grand fir; Cold UF assumes a species mix of 10% Douglas-fir, 10% western larch, 50% lodgepole pine, 20% Engelmann spruce, and 10% subalpine fir. Powell (2009d) provides additional density-class metrics in the form of stand density index, trees per acre, and canopy cover.

USING RV TO EVALUATE CANOPY FUEL LOADING

When considering fire effects on vegetation and other ecosystem components, crown fire is acknowledged to be the most severe of three fire types, which consist of ground fire, surface fire, and crown fire (Pyne et al. 1996). Although some amount of crown fire is normal and expected for fire regime groups III, IV, and V (Schmidt et al. 2002), a large amount of crown fire is neither normal nor expected for the dry forests of fire regime group I (Agee 1993).

Because dry forests are affected by crown fire with increasing regularity (Mutch et al. 1993), and as treatments are being planned for the wildland-urban interface where crown fire can seldom be tolerated regardless of fire regime, fire managers need tools to help them evaluate crown fire susceptibility for all forested lands. To help meet this need, range of variation information was developed for three classes of canopy fuel loading (canopy biomass); it is stratified by potential vegetation group (PVG is broadly correlated with fire regime) and provided in table 7.

Table 7: Range of variation information for canopy biomass classes, expressed as percentages by potential vegetation group.

Potential Vegetation Group	Fire Regime Group[2]	CANOPY BIOMASS CLASS[1] Low (≤.05 kg/m^3 CBD)	Moderate (.06-.09 kg/m^3 CBD)	High (≥.10 kg/m^3 CBD)
		Range of Variation (Percentage)		
Dry Upland Forest	I	60-90	20-60	10-20
Moist Upland Forest	III	20-50	50-70	20-50
Cold Upland Forest	IV	10-20	20-60	60-90

Source/Notes: Based on Agee (1998). Potential vegetation group is described in Powell et al. (2007).

[1] Canopy biomass class is a derived database field; it can be calculated by using queries contained in Powell (2010). CBD is crown bulk density, expressed as kilograms per cubic meter of crown volume. Class breakpoints are as follows: .05 kg/m^3 = CBD threshold below which crown fire is unlikely; .10 kg/m^3 = CBD threshold above which crown fire is easily sustained (Powell 2010).

[2] Fire regime group describes the fire environment by characterizing fire frequency, fire intensity, fire severity, fire extent, fire timing, and historical burned area (Schmidt et al. 2002). For forest environments in the Blue Mountains, three fire regime groups are most important: Fire regime group I: surface; Fire regime group III: mixed; Fire regime group IV: replacement.

USING RV TO EVALUATE INSECT AND DISEASE SUSCEPTIBILITY

RV is not intended to characterize a static, unchanging environment. It reflects the effects of ecological processes with important implications on ecosystem behavior, such as the capacity of an ecosystem to function effectively in a constantly changing environment. Ecosystems of the interior Pacific Northwest evolved with a steady diet of fires, insect outbreaks, disease epidemics, floods, landslides, human uses, and weather cycles. Change was, and still is, the only constant in their existence. RV is designed to characterize the range of vegetation composition, structure, and density resulting from these agents of change (Morgan et al. 1994).

Do insect outbreaks and disease epidemics indicate that ecosystems are unhealthy? And what do large, landscape-scale fires indicate in an ecological context? Since ecosystems are constantly changing, we need to evaluate their health in a similar context. Resilient forests not only tolerate periodic disturbance, they may depend on it for rejuvenation and renewal (Johnson et al. 1994). Significant changes in the magnitude (extent), intensity, or pattern of disturbance, however, may be indicative of impaired ecological integrity (Sampson and Adams 1994).

Perhaps the most effective framework for evaluating forest health is the range of variation – are the effects of changes caused by insects, diseases, and wildfire consistent with what would be expected (the RV) for similar ecosystems and vegetative conditions? Recent forest health assessments for the Blue Mountains, for example, suggest it might be appropriate to characterize dry forest ecosystems as out-of-balance (Powell 2014).

When dry forests are evaluated by using an RV context, recently high levels of insect and disease activity are not totally unexpected, but they are still a symptom of the underlying problem – the composition, structure, and density of these ecosystems are currently outside of their RV (Caraher et al. 1992, Gast et al. 1991, Hessburg et al. 1994, Mutch et al. 1993, Oliver et al. 1994, Sampson and Adams 1994, Shlisky 1994, Wickman 1992).

Since composition, structure, and density change as forest development progresses, it is important that land managers understand how forest succession influences insect, disease, and crown-fire susceptibility to ensure that management activities are placed on a sound ecological foundation: "manipulation of a forest ecosystem should work within the limits established by natural disturbance patterns prior to extensive human alteration of the landscape" (Hunter 1999, page 29).

Susceptibility is defined as a set of conditions that make a forest stand vulnerable to substantial injury from insects or diseases. Susceptibility assessments do not predict when insects or diseases might reach damaging levels; rather, they indicate whether stand conditions are conducive to declining forest health, as reflected by increasing levels of tree mortality from insect and disease organisms.

Drought, ecological site potential (potential vegetation type), species composition and abundance, tree size, forest structure (canopy layering, structural stage), stocking (stand density), intra-stand variability (clumpiness), and other biophysical factors influence susceptibility and vulnerability to insect and disease disturbances (Hessburg et al. 1999, Lehmkuhl et al. 1994, Schmitt and Powell 2005).

Trees with increased insect or disease susceptibility often occur in dense forests where they face greater competition for soil moisture, nutrients, and other resources. Ponderosa pines in high-density stands, for example, have lower xylem water potentials and rates of photosynthesis, indicating greater drought stress (i.e., high tree density causes physiological drought, in contrast to climatic drought resulting from reduced precipitation). These stressed trees have decreased resin production and foliar toughness, suggesting an increased susceptibility to insect and pathogen attack (Kolb et al. 1998).

Once lodgepole pine, ponderosa pine, and other coniferous species respond physiologically to thinning (typically in 3 to 5 years after crowns and roots expand into growing space liberated by the thinning), their improved vigor promotes increased production of defensive chemicals and resins enhancing beetle resistance (Bradley 1963, Christiansen et al. 1987; Feeney et al. 1998; Franceschi et al. 2005; Kolb et al.

1998, 2007; McDowell et al. 2007; Mitchell and Martin 1980; Perrakis and Agee 2006; Shrimpton 1978; Wallin et al. 2008).

To provide a process for evaluating insect and disease susceptibility, range of variation information was developed for nine insect and disease agents, and three classes of susceptibility (high, moderate, low); it is stratified by potential vegetation group and provided in table 8.

Table 8: Range of variation information for insect and disease susceptibility, expressed as percentages by agent and potential vegetation group.

Insect and Disease Agents[1]	POTENTIAL VEGETATION GROUP (PVG) Dry UF	Moist UF	Cold UF
	Range of Variation (Percentage)		
Defoliating insects			
Low susceptibility	40-85	5-20	40-95
Moderate susceptibility	15-30	20-30	15-25
High susceptibility	5-15	35-80	5-10
Douglas-fir beetle			
Low susceptibility	35-75	30-60	45-95
Moderate susceptibility	15-30	20-40	10-25
High susceptibility	10-25	10-30	5-10
Fir engraver			
Low susceptibility	45-95	30-70	35-75
Moderate susceptibility	10-25	10-20	20-45
High susceptibility	5-10	20-40	5-10
Spruce beetle			
Low susceptibility	0-0	50-95	10-30
Moderate susceptibility	0-0	10-25	30-50
High susceptibility	0-0	0-10	20-50
Bark beetles in ponderosa pine			
Low susceptibility	35-75	30-65	55-95
Moderate susceptibility	15-35	15-30	5-30
High susceptibility	10-20	15-35	0-5
Mountain pine beetle in lodgepole pine			
Low susceptibility	55-90	30-60	30-50
Moderate susceptibility	5-35	25-40	15-40
High susceptibility	0-5	5-30	15-40
Douglas-fir dwarf mistletoe			
Low susceptibility	30-60	30-65	40-90
Moderate susceptibility	10-35	20-45	20-30
High susceptibility	20-35	10-20	0-10
Western larch dwarf mistletoe			
Low susceptibility	55-95	5-20	10-20
Moderate susceptibility	5-30	15-40	20-50
High susceptibility	0-5	40-70	30-60

Insect and Disease Agents[1]	POTENTIAL VEGETATION GROUP (PVG) Dry UF	Moist UF	Cold UF
Root diseases			
Low susceptibility	35-75	5-25	30-65
Moderate susceptibility	20-35	20-40	20-45
High susceptibility	5-20	35-65	10-15

Sources/Notes: Derived from Schmitt and Powell (2012). Queries for calculating susceptibility ratings are available from Schmitt and Powell (2005). PVG is described in Powell et al. (2007).

[1] Defoliating insects includes western spruce budworm and Douglas-fir tussock moth; bark beetles in ponderosa pine includes western and mountain pine beetles; root diseases include laminated root rot and Armillaria root disease.

GLOSSARY

Biophysical environment. Landscape-level unit of composition and structure, with its associated environmental gradients and processes of change (Quigley and Arbelbide 1997).

Cover type. The plant species forming a plurality of the composition across a given land area, e.g., the Engelmann spruce-subalpine fir, ponderosa pine-Douglas-fir, or lodgepole pine forest cover types (Helms 1998). Forest cover types of the United States and Canada are described in Eyre (1980). Rangeland cover types of the United States are described in Shiflet (1994).

Disturbance. A relatively discrete event that disrupts the structure of an ecosystem, community or population, and changes resource availability or the physical environment. Disturbances include processes such as fires, floods, insect outbreaks, disease epidemics, and windstorms (Dodson et al. 1998).

Disturbance regime. The spatial and temporal dynamics of disturbance events over a long time period. Characterizing a disturbance regime would include attributes such as the spatial distribution of disturbance events; disturbance frequency (number of disturbance events in a specified time interval, or the probability of a disturbance event occurring within a particular time interval); return interval (average time between successive disturbance events); rotation period (length of time until an area equivalent to the size of an analysis area would be affected in one disturbance event); disturbance size; and the magnitude, or intensity, of a disturbance event (Dodson et al. 1998).

Ecosystem. A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of the abiotic environment within its boundaries. An ecosystem is commonly described in terms of its: (1) Composition. The biological elements within the different levels of biological organization, from genes and species to communities and ecosystems. (2) Structure. The organization and physical arrangement of biological elements such as, snags and down woody debris, vertical and horizontal distribution of vegetation, stream habitat complexity, landscape pattern, and connectivity. (3) Function. Ecological processes that sustain composition and structure, such as energy flow, nutrient cycling and retention, soil

development and retention, predation and herbivory, and natural disturbances such as wind, fire, and floods. (4) Connectivity. (USDA Forest Service 2012a).

Landscape. A defined area irrespective of ownership or other artificial boundaries, such as a spatial mosaic of terrestrial and aquatic ecosystems, landforms, and plant communities, repeated in similar form throughout such a defined area (USDA Forest Service 2012a).

Plant association. A plant community with similar physiognomy (form and structure) and floristics; commonly it is a climax community (Allaby 1998). It is believed that (1) the individual species in the association are, to some extent, adapted to each other; (2) the association is made up of species that have similar environmental requirements; and (3) the association has some degree of integration (Kimmins 1997).

Potential vegetation. The vegetation that would become established if successional sequences were completed without interference by man or natural disturbance under present climatic and edaphic conditions; the plant community developing if all successional sequences were completed under existing site conditions (Dunster and Dunster 1996).

Potential vegetation group (PVG). An aggregation of plant association groups with similar environmental regimes (temperature or moisture relationships) and dominated by similar types of plants (Powell et al. 2007).

Range of variation (historical range of variability). A characterization of fluctuations in ecosystem conditions or processes over time; an analytical technique used to define the bounds of ecosystem behavior that remain relatively consistent through time (Morgan and others 1994). Values of composition, structure, or another attribute, and falling between upper and lower bounds determined for the attribute (Jennings et al. 2003), are said to be within the range of variation. Attributes whose values occur above the upper bound are said to be 'over-represented;' attributes whose values are below the lower bound are said to be 'under-represented' (see fig. 1). "The range of variation under historic disturbance regimes is an important context to evaluate current and desired conditions; however, it should not necessarily be used as the desired condition itself" (FSH 1909.12, Land Management Planning Handbook, section 43.13 – Range of variation).

Reference conditions. A reference ecosystem or reference conditions can serve as a model for planning ecosystem restoration activities. In its simplest form, the reference is an actual site, its written description (such as historical accounts of a reference area), or both (Society for Ecological Restoration 2004). Reference conditions also refer to a range of variation in ecological structures and processes, reflecting recent evolutionary history and the dynamic interplay of biotic and abiotic factors. Reference conditions generally reflect ecosystem properties that are free of major influence by Euro-American humans (Kaufmann et al. 1994).

Resilience. Intrinsic properties allowing the fundamental functions of an ecosystem to persist in the presence of disturbance; the 'bounce-back' capability of a system to recover from disturbance. "Ecological resilience is the capacity of an eco-

system to absorb disturbance and undergo change while maintaining its essential functions, structures, identity, and feedbacks. Resilience is often synonymous with adaptive capacity, i.e., the ability of a system to reconfigure itself in the face of disturbance or stresses without significant decreases in critical aspects such as productivity or composition" (Drever et al. 2006). Resilience recognizes that systems have a capacity to absorb disturbance, but this capacity has limits and when they are exceeded, the system may rapidly transition to a different state or developmental trajectory (Gunderson et al. 2010). In a climate-change context, resilience is sometimes viewed as analogous to adaptation.

Resistance. Resistance refers to the ability of an ecosystem to remain relatively unchanged in the face of external forces such as disturbance (pulse-type changes) or climate change. Resistance is sometimes viewed as being analogous to stability (Holling 1973), but in a climate-change context, it is often viewed as analogous to mitigation.

Seral stage: a stage of secondary successional development (secondary succession refers to an ecological process of progressive changes in a plant community after stand-initiating disturbance). Four seral stages are recognized: early seral, mid seral, late seral, and potential natural community (Hall et al. 1995).

> **Early seral**: clear dominance of pioneer species (western larch, ponderosa pine, lodgepole pine, etc.); PNC species absent, or present in very low numbers.
>
> **Mid seral**: PNC species are increasing in the forest composition as a result of their active colonization of the site; PNC species are approaching equal proportions with the early-seral species.
>
> **Late seral**: PNC species are dominant, although long-lived, early-seral species (ponderosa pine, western larch, etc.) may still be present in low numbers.
>
> **Potential natural community** (PNC): the biotic community presumably established and maintained under present environmental conditions; early- or mid-seral species are scarce or absent entirely in the plant composition.

Species composition. Identity of species in an ecosystem (Chapin et al. 2002).

Structural stage. A stage or recognizable condition that relates to the physical orientation and arrangement of vegetation; the size and arrangement (both vertical and horizontal) of trees and tree parts. The following structural stages have been described (O'Hara et al. 1996, Oliver and Larson 1996; also see table 3):

> **Stand initiation**: one canopy stratum of seedlings and saplings is present; grasses, forbs, and shrubs typically coexist with the trees.
>
> **Stem exclusion**: one canopy stratum comprised mostly of pole-sized trees (5-8.9" DBH) is present. The canopy layer may be open (stem exclusion open canopy) on sites where moisture is limiting, or closed (stem exclusion closed canopy) on sites where light is a limiting resource.
>
> **Understory reinitiation**: two canopy strata are present; a second tree layer is established under an older overstory. Overstory mortality creates growing space for establishment of understory trees.

Old forest: a predominance of large trees (>21" DBH) is present in a stand with one or more canopy strata. On warm dry sites with frequent, low-intensity fires, a single stratum may be present (old forest single stratum). On cool moist sites without recurring underburns, multi-layer stands with large trees in the uppermost stratum may be present (old forest multi strata).

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APPENDIX: SILVICULTURE WHITE PAPERS

White papers are internal reports, and they are produced with a consistent formatting and numbering scheme – all papers dealing with Silviculture, for example, are placed in a silviculture series (Silv) and numbered sequentially. Generally, white papers receive only limited review and, in some instances pertaining to highly technical or narrowly focused topics, the papers may receive no technical peer review at all. For papers that receive no review, the viewpoints and perspectives expressed in the paper are those of the author only, and do not necessarily represent agency positions of the Umatilla National Forest or the USDA Forest Service.

Large or important papers, such as two papers discussing active management considerations for dry and moist forests (white papers Silv-4 and Silv-7, respectively), receive extensive review comparable to what would occur for a research station general technical report (but they don't receive blind peer review, a process often used for journal articles).

White papers are designed to address a variety of objectives:

(1) They guide how a methodology, model, or procedure is used by practitioners on the Umatilla National Forest (to ensure consistency from one unit, or project, to another).
(2) Papers are often prepared to address ongoing and recurring needs; some papers have existed for more than 20 years and still receive high use, indicating that the need (or issue) has long standing – an example is white paper #1 describing the Forest's big-tree program, which has operated continuously for 25 years.
(3) Papers are sometimes prepared to address emerging or controversial issues, such as management of moist forests, elk thermal cover, or aspen forest in the Blue Mountains. These papers help establish a foundation of relevant literature, concepts, and principles that continuously evolve as an issue matures, and hence they may experience many iterations through time. [But also note that some papers have not changed since their initial development, in which case they reflect historical concepts or procedures.]
(4) Papers synthesize science viewed as particularly relevant to geographical and management contexts for the Umatilla National Forest. This is considered to be the Forest's self-selected 'best available science' (BAS), realizing that non-agency commenters would generally have a different conception of what constitutes BAS – like beauty, BAS is in the eye of the beholder.
(5) The objective of some papers is to locate and summarize the science germane to a particular topic or issue, including obscure sources such as master's theses or Ph.D. dissertations. In other instances, a paper may be designed to wade through an overwhelming amount of published science (dry-forest management), and then synthesize sources viewed as being most relevant to a local context.
(6) White papers function as a citable literature source for methodologies, models, and procedures used during environmental analysis – by citing a white paper,

specialist reports can include less verbiage describing analytical databases, techniques, and so forth, some of which change little (if at all) from one planning effort to another.

(7) White papers are often used to describe how a map, database, or other product was developed. In this situation, the white paper functions as a 'user's guide' for the new product. Examples include papers dealing with historical products: (a) historical fire extents for the Tucannon watershed (WP Silv-21); (b) an 1880s map developed from General Land Office survey notes (WP Silv-41); and (c) a description of historical mapping sources (24 separate items) available from the Forest's history website (WP Silv-23).

These papers are available from the Forest's website: Silviculture White Papers

Paper #	Title
1	Big tree program
2	Description of composite vegetation database
3	Range of variation recommendations for dry, moist, and cold forests
4	Active management of dry forests in the Blue Mountains: silvicultural considerations
5	Site productivity estimates for upland forest plant associations of the Blue and Ochoco Mountains
6	Fire regimes of the Blue Mountains
7	Active management of moist forests in the Blue Mountains: silvicultural considerations
8	Keys for identifying forest series and plant associations of the Blue and Ochoco Mountains
9	Is elk thermal cover ecologically sustainable?
10	A stage is a stage is a stage…or is it? Successional stages, structural stages, seral stages
11	Blue Mountains vegetation chronology
12	Calculated values of basal area and board-foot timber volume for existing (known) values of canopy cover
13	Created openings: direction from the Umatilla National Forest land and resource management plan
14	Description of EVG-PI database
15	Determining green-tree replacements for snags: a process paper
16	Douglas-fir tussock moth: a briefing paper
17	Fact sheet: Forest Service trust funds
18	Fire regime condition class queries
19	Forest health notes for an Interior Columbia Basin Ecosystem Management Project field trip on July 30, 1998 (handout)
20	Height-diameter equations for tree species of the Blue and Wallowa Mountains

Paper #	Title
21	Historical fires in the headwaters portion of the Tucannon River watershed
22	Range of variation recommendations for insect and disease susceptibility
23	Historical vegetation mapping
24	How to measure a big tree
25	Important insects and diseases of the Blue Mountains
26	Is this stand overstocked? An environmental education activity
27	Mechanized timber harvest: some ecosystem management considerations
28	Common plants of the south-central Blue Mountains (Malheur National Forest)
29	Potential natural vegetation of the Umatilla National Forest
30	Potential vegetation mapping chronology
31	Probability of tree mortality as related to fire-caused crown scorch
32	Review of the "Integrated scientific assessment for ecosystem management in the interior Columbia basin, and portions of the Klamath and Great basins" – forest vegetation
33	Silviculture facts
34	Silvicultural activities: description and terminology
35	Site potential tree height estimates for the Pomeroy and Walla Walla ranger districts
36	Tree density protocol for mid-scale assessments
37	Tree density thresholds as related to crown-fire susceptibility
38	Umatilla National Forest Land and Resource Management Plan: forestry direction
39	Updates of maximum stand density index and site index for the Blue Mountains variant of the Forest Vegetation Simulator
40	Competing vegetation analysis for the southern portion of the Tower Fire area
41	Using General Land Office survey notes to characterize historical vegetation conditions for the Umatilla National Forest
42	Life history traits for common conifer trees of the Blue Mountains
43	Timber volume reductions associated with green-tree snag replacements
44	Density management field exercise
45	Climate change and carbon sequestration: vegetation management considerations
46	The Knutson-Vandenberg (K-V) program
47	Active management of quaking aspen plant communities in the northern Blue Mountains: regeneration ecology and silvicultural considerations
48	The Tower Fire…then and now. Using camera points to monitor postfire recovery
49	How to prepare a silvicultural prescription for uneven-aged management

Paper #	Title
50	Stand density conditions for the Umatilla National Forest: a range of variation analysis
51	Restoration opportunities for upland forest environments of the Umatilla National Forest
52	New perspectives in riparian management: Why might we want to consider active management for certain portions of riparian habitat conservation areas?
53	Eastside Screens chronology
54	Using mathematics in forestry: an environmental education activity
55	Silviculture certification: tips, tools, and trip-ups
56	Vegetation polygon mapping and classification standards: Malheur, Umatilla, and Wallowa-Whitman national forests
57	The state of vegetation databases on the Malheur, Umatilla, and Wallowa-Whitman national forests

REVISION HISTORY

May 2010: the first version formatted with a new white-paper template (see top of page 1) was released and posted to the Forest's website.

March 2012: minor formatting and text edits were made; table 7 was revised to incorporate revised RV ranges from Schmitt and Powell (2012).

November 2012: minor formatting and text edits were made, including additional literature references; a table of contents was added; appendix 2 was added describing the white paper system, including a list of available white papers.

January 2014: formatting and text edits were made throughout, including a minor revision of the white paper template format on page 1; additional verbiage about Fire Regime Condition Class assessments was added; and in response to many requests from Forest Service users of this white paper, substantial additional verbiage about the relationships and interactions between project planning and RV analysis was added as a new section entitled "Project planning and RV."